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Natural Resource Stewardship and Science

Condition Assessment of Streambanks and Streamside Vegetation on Perennial Streams in Wind Cave National Park

2009-2012

Natural Resource Technical Report NPS/WICANRTR—2013/758

ON THE COVER
Clockwise from upper left: determining plant species composition in Multiple Indicator Monitoring (MIM) frame at Wind Cave National Park in Highland Creek 2 Designated Monitoring Area (DMA); dragonfly and aquatic vegetation in Highland Creek; MIM monitoring crew working in Beaver Creek 1 DMA; MIM monitoring team working in Beaver Creek 3 DMA.

Photographs courtesy of Wind Cave National Park

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This report received formal, high-level peer review based on the importance of its content, or its potentially controversial or precedent-setting nature. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

This report is available from the Wind Cave National Park website (http://www.nps.gov/wica/naturescience/research-bibliography.htm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

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Executive Summary

A project was developed and implemented at Wind Cave National Park (WICA) by WICA Resource Management personnel using the BLM Multiple Indicator Monitoring of Streambanks and Streamside Vegetation (MIM) protocol. The purpose of the project was to assess condition of WICA perennial streams relative to production of ecological services, including forage and browse production; wildlife use; species richness (plant and animal); compositional, structural, and functional diversity; and hydrologic function. MIM measurements were made for baseline condition assessment in 2009-2010 from nine Designated Monitoring Areas (DMA) on the three perennial streams in the park: Beaver Creek, Highland Creek, and Cold Spring Creek. MIM measurements were again collected in seven DMAs in 2012 to provide information on change in condition (Cold Spring Creek was dry in 2012 so data could not be collected in two DMAs).

Streamside condition was extrapolated to the full lengths of Beaver Creek and Highland Creek by identifying and ground-checking segments similar to representative DMAs. Both Beaver and Highland Creeks were categorized in poor ecological condition and stable from 2009 to 2012. Wildlife population numbers and other disturbances and management activities stayed essentially the same in WICA from 2009 to 2012. MIM data from Cold Spring Creek in 2010 indicated poor ecological condition in the two DMAs. No change information was produced and DMA data were not extrapolated to assess overall stream condition of Cold Spring Creek.

Based on MIM indicators, WICA perennial streams are primarily providing an important ecological service of water for wildlife. However, other ecosystem services are at risk and vulnerable to future reductions or losses. Given projections of climate change impacts in WICA, it is unlikely that the limited surface water resources in WICA, especially perennial streams, will be able to provide a wide range of desired ecological services without strategic management. The results of this project could provide a foundation for development of a WICA Surface Water Resource Management Strategy, including prioritization of desired ecological services for WICA perennial streams, identification of streams/segments with different goals and objectives, and development of possible management tools (short and long term) as well as triggers for implementation.

Because of differences between the past and today as well as a lack of data, it is not possible to know what changes occurred in riparian plant species and plant communities as a result of past bottleneck periods of high disturbance (such as drought and intensive grazing). However, it seems certain that management of WICA perennial streams today should consider the concepts of refugia and persistence of plant species that are sensitive to disturbances in order to conserve and protect present-day WICA vegetation into the future.

Acknowledgments

This project could not have been completed without the help of many monitoring hands in the field. We thank WICA seasonal vegetation crew members (Kevin Miller, Laura Nelson, Ryan Gamett), Northern Great Plains Network (NGPN) Inventory and Monitoring personnel (Isabel Ashton, Michael Prowatzke, Gretchen Addington, Lauren Baur, Daina Jackson, Ryan Manuel, and Timothy Pine), and Marc Ohms, WICA Physical Science Technician.

Many people reviewed this report through management, technical, and peer reviews. All comments were useful and appreciated, especially those of Amy Symstad and Isabel Ashton.

Consultation with Ervin R. Cowley (one of the MIM protocol authors) and the Black Hills MIM Project team allowed for best possible application of the MIM protocol to the WICA project in the areas of data collection, data analysis, and data interpretation. Development of a Black Hills-wide MIM data set in the coming years from work by federal, state, and private entities could improve understanding of Black Hills streams and support effective stewardship of surface water, streambanks, and streamside vegetation into an uncertain ecological future.

List of Acronyms

BHCI	Black Hills Community Inventory
BLM	Bureau of Land Management
CI	Confidence interval
CV	Coefficient of variation
DMA	Designated monitoring area
GGW	Greenline to greenline width
in	inch
m	meter
MIM	Multiple Indicator Monitoring of Streambanks and Streamside Vegetation
NGP I&M	Northern Great Plains Inventory and Monitoring Network
NPS	National Park Service
S/N	Signal to noise ratio
SH	Stubble height
USDI	U.S. Department of the Interior
USFS	U.S. Forest Service
USNVC	U.S. National Vegetation Classification
WICA	Wind Cave National Park

Introduction

Wind Cave National Park (WICA) encompasses 33,851 acres in the southern Black Hills of South Dakota. The purpose of the park is to protect the unique resources of Wind Cave and preserve and enhance mixed-grass prairie and native wildlife, while providing for the enjoyment of the public (WICA Foundation Statement 2011). The park is a mosaic of ponderosa pine forest and mixed-grass prairie, with approximately 30% covered with ponderosa pine forest. Although streams and their associated riparian vegetation make up less than 1% of WICA land surface, they are critical for the ecosystem services they provide. Ecosystem services include forage and browse production; wildlife use; species richness (plant and animal); compositional, structural, and functional diversity; visitor opportunities for education and enjoyment; and hydrologic function.

There are three perennial streams in WICA: Beaver Creek, Highland Creek and Cold Spring Creek. There are excellent summaries of the physical context of WICA surface water in the Water Resources of Wind Cave NP - 2012 Update (Ohms 2012) and the WICA 2011 Natural Resource Condition Assessment (Komp et al. 2011). Although the WICA 2011 Natural Resource Condition Assessment concludes that “Surface and groundwater resources in WICA are well documented and have been studied extensively” (Komp et al. 2011), this refers only to stream flow and water quality. In particular, there is very little information available to describe riparian/streamside vegetation, streambank condition, and stream substrate - and no data exist on changes or trends in these attributes over time.

WICA was recognized in the Black Hills Community Inventory (BHCI; Marriott et al. 1999a) as an exemplary site – a site with outstanding size, outstanding landscape context (including little landscape fragmentation), a diverse set of community types present, and high quality occurrences for those types. WICA was noted as including 22 community types, including 9 rare community types, one of which was Western Great Plains Streamside Vegetation (NatureServe rounded global rank: G3 – Vulnerable). The riparian streambank vegetation recognized as exemplary in 1999 was not comprehensively described, given that the BHCI data set consisted of two plots (Marriott et al. 1999b). Since 1999, WICA has embraced the concept that riparian/streambank vegetation in the park is rare and exemplary and in good condition but has conducted no further monitoring or analysis.

Part of WICA’s purpose is to preserve and enhance native wildlife populations including bison, elk, pronghorn, mule deer, whitetail deer, and prairie dogs (WICA Foundation Statement 2011). In 1998, when data from BHCI riparian plots were collected, there were 250-300 elk in the park and ca 325 bison (Roddy pers. comm. 2013). Today, there are ca 900 elk in the park and 400-425 bison (Roddy pers. comm. 2013). The difference in animal numbers is highly likely to contribute to different riparian/streamside conditions between 1999 and today. Variation in precipitation adds to different quantity and distribution of water in streams – impacting the ecological services streams can provide (including water for wildlife).

Another part of WICA’s purpose is to preserve and enhance mixed-grass prairie, ponderosa pine, and riparian plant communities (WICA Foundation Statement 2011). A desired condition of WICA is that hydrological processes and the quality and quantity of surface and subsurface water are maintained and protected to support wildlife, vegetation, and cave resources (WICA Foundation Statement 2011). Plant species data (SD Natural Heritage Database and WICA herbarium) suggest that WICA has been under-studied from a comprehensive floristics perspective and from a specific riparian perspective. However, field observations of relatively low vegetation diversity in WICA riparian/streambank areas by the WICA botanist (author, B. Burkhart) indicate that past conditions may have impacted the persistence of some riparian species. Most ecological systems have common, abundant species that are often hardier with respect to disturbances than uncommon, sparse species in those systems. These are sometimes referred to as persistent (common, abundant, resilient) species and sensitive (uncommon, sparse, vulnerable) species. Generally, sensitive species may require refugia in the landscape where factors such as natural variability in topography, geomorphology, hydrology, vegetation characteristics, etc. allow them to survive periods of high intensity or high frequency disturbance.

Some riparian species are very sensitive to disturbances such as grazing and trampling (Clary and Webster 1989; Clary and Webster 1990; Clary et al. 1996). A riparian system with adequate natural variability (e.g., topography, geomorphology, geology, hydrology) or constructed variability (e.g. fenced exclosures) can provide refugia for sensitive species from some disturbances, particularly during periods of high intensity or high frequency disturbance. Riparian systems in the park may not have provided adequate refugia for disturbance-sensitive riparian species in past periods of low precipitation and high animal use since the park boundary fence was completed in 1953. This could result in bottleneck periods when sensitive species diversity is decreased and not able to recover because seedbank reserves do not exist or have been depleted and/or riparian areas are too far from seed/propagule sources for repopulation.

Regular monitoring and analysis provides a science-based approach for detecting changes in water quantity, distribution, use, and associated riparian/streambank vegetation. A lack of riparian/streambank data for WICA was recognized by WICA Resource Management staff in 2008. A review of monitoring protocols resulted in the choice of the BLM/USFS Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation (Burton et al. 2008) protocol as a broad-based and efficient tool for assessing condition status and trend on WICA perennial streams. The MIM protocol was developed and tested on relatively low-gradient (less than 4 percent), perennial, snowmelt-dominated and spring-fed streams in the western United States and is most applicable to those systems. The MIM protocol is designed to be objective, efficient, and effective for monitoring streambanks, stream channels, and streamside riparian vegetation. The MIM protocol combines observations of up to 10 indicators along the same stream reach into one protocol. Travel to field sites can require a considerable time commitment, so the collection of more than one indicator at one location with one protocol maximizes efficiency.

Ervin Cowley, one of the authors of the protocol (now retired BLM), has visited the Black Hills several times to conduct training in implementing the MIM protocol. The author (B. Burkhart) attended MIM trainings in the Black Hills in 2007 and 2008; Cowley returned to the Black Hills in 2012 and other members of the WICA/Northern Great Plains Inventory and Monitoring (NGP I&M) riparian monitoring team attended the 2012 training session. Interaction with Cowley has allowed best practice application of the MIM protocol in the Black Hills area.

Although called for in the Northern Great Plains Inventory and Monitoring (NGP I&M) plan (Gitzen et al. 2010), the network's plant community monitoring protocol (Symstad et al. 2012) does not yet have methods specific to riparian vegetation. NGP I&M adopted the WICA riparian monitoring effort started in 2009 as a test program and contributed personnel and equipment to collecting and processing 2012 data.

This report documents results from 2009, 2010, and 2012 riparian monitoring efforts in WICA using the MIM protocol and makes preliminary conclusions on condition for WICA streams and streambank vegetation on the three perennial streams in the park (Beaver Creek, Highland Creek, and Cold Spring Creek).

Methods

The WICA MIM project used the MIM 2008 version for data collected in 2009, 2010, and 2012. With the assistance of Ervin R. Cowley, WICA MIM data in the 2008 format was translated into an updated 2013 format to take advantage of improved and additional analysis tools.

Sample Design

The first step in applying the MIM protocol is locating the designated monitoring area (DMA) - the location on the stream where all monitoring procedures occur. There are several considerations for setting up an appropriate DMA, depending on the purpose of the monitoring. The MIM protocol begins with stratifying a stream into segments with similar vegetation and physical characteristics, as well as land uses. Similar segments are identified as the same riparian complex. One or more complexes can be selected for monitoring. Generally, the complexes that are most sensitive to management influence should be used for monitoring. When the chosen complexes are located, the location of the DMA is randomly selected within the complex, resulting in a stratified random sampling design (BLM 2011).

There are three types of DMAs:
Representative DMA – A monitoring site in a riparian complex that is representative of a larger area. Representative DMAs should be located within a single riparian complex. When more than one riparian complex occurs in a management unit, the DMA should be placed in the complex that is most sensitive to management influence. The premise is that if the DMA is placed in the most sensitive complex and that complex is being monitored and managed to achieve desired conditions, then other less sensitive complexes will also be managed appropriately.

Critical DMA – A reach that is not representative of a larger area but is important enough that specific information is needed at that particular site. Critical DMAs are monitored for highly localized purposes and to address site-specific questions. Extrapolating data from a critical DMA to a larger area may not be appropriate.

Reference DMA – A reach chosen to obtain reference data useful for identifying potential condition and establishing initial desired condition objectives for a similar riparian complex. A common example is a grazing exclosure where large herbivore access to the stream is restricted. Reference DMAs meet many of the same criteria as representative DMAs.

We chose the DMAs for the WICA MIM project to function as representative and reference DMAs relative to wildlife/large herbivore use and geomorphology (Table 1).

Table 1. Information about DMAs established for WICA MIM project.

Stream	DMA/GPS coordinate at start (UTM NAD 83)	DMA type (level of wildlife/large herbivore use; geomorphology)	DMA length/ # plots	Dates monitored:		
Beaver Creek				**2009**	**2010**	**2012**
	Beaver Creek Exclosure N4826440.35 E622779.69	Reference (minimal use by wildlife; wide valley)	100m/ 70 plots	-----	Sept 29	Sept 10
	Beaver Creek 1 N4826528.4 E623018.68	Representative (heavily used by wildlife; wide valley)	110m/ 80 plots	Aug 13	-----	Aug 29
	Beaver Creek 2 N4826569.28 E623465.22	Representative (less used by wildlife; wide valley)	110m/ 80 plots	Aug 13	-----	Aug 29
	Beaver Creek 3 N4827123.08 E621464.98	Representative (less used by wildlife; narrow valley)	110 m/ 80 plots	-----	Aug 12&17	Sept 12
Highland Creek						
	Highland Creek Exclosure N4831699.78 E626094.56	Reference (minimal use by wildlife; wide valley)	60 m/ 40 plots	-----	Sept 9	Sept 12
	Highland Creek 1 N4831250.5 E625864.88	Representative (less used by wildlife; narrow valley)	110m/ 80 plots	Aug 14	-----	Aug 30
	Highland Creek 2 N4831737.22 E626016.8	Representative (heavily used by wildlife; wide valley)	110m/ 80 plots	Aug 20	-----	Aug 30
Cold Spring Creek						
	Cold Spring Creek Exclosure N4825829.24 E622482.85	Reference (minimal use by wildlife; wide valley)	90m/ 62 plots	-----	Sept 8	Aug 30: dry-no data
	Cold Spring Creek 1 N4825874.9 E622447.11	Representative (heavily utilized by wildlife; wide valley)	110m/ 80 plots	-----	Aug 26	Aug 30: dry-no data

Three representative DMAs (Beaver Creek 1, Beaver Creek 2, and Beaver Creek 3) and one reference DMA (Beaver Creek Exclosure) were established on Beaver Creek (Fig. 1). Beaver Creek Exclosure and Beaver Creek 3 DMAs are upstream of the confluence of Beaver Creek (the larger/dominant stream) and Cold Spring Creek, whereas Beaver Creek 1 and Beaver Creek 2 DMAs are downstream of the confluence. This adds some complexity to comparisons among Beaver Creek DMAs but was not quantified for this project.

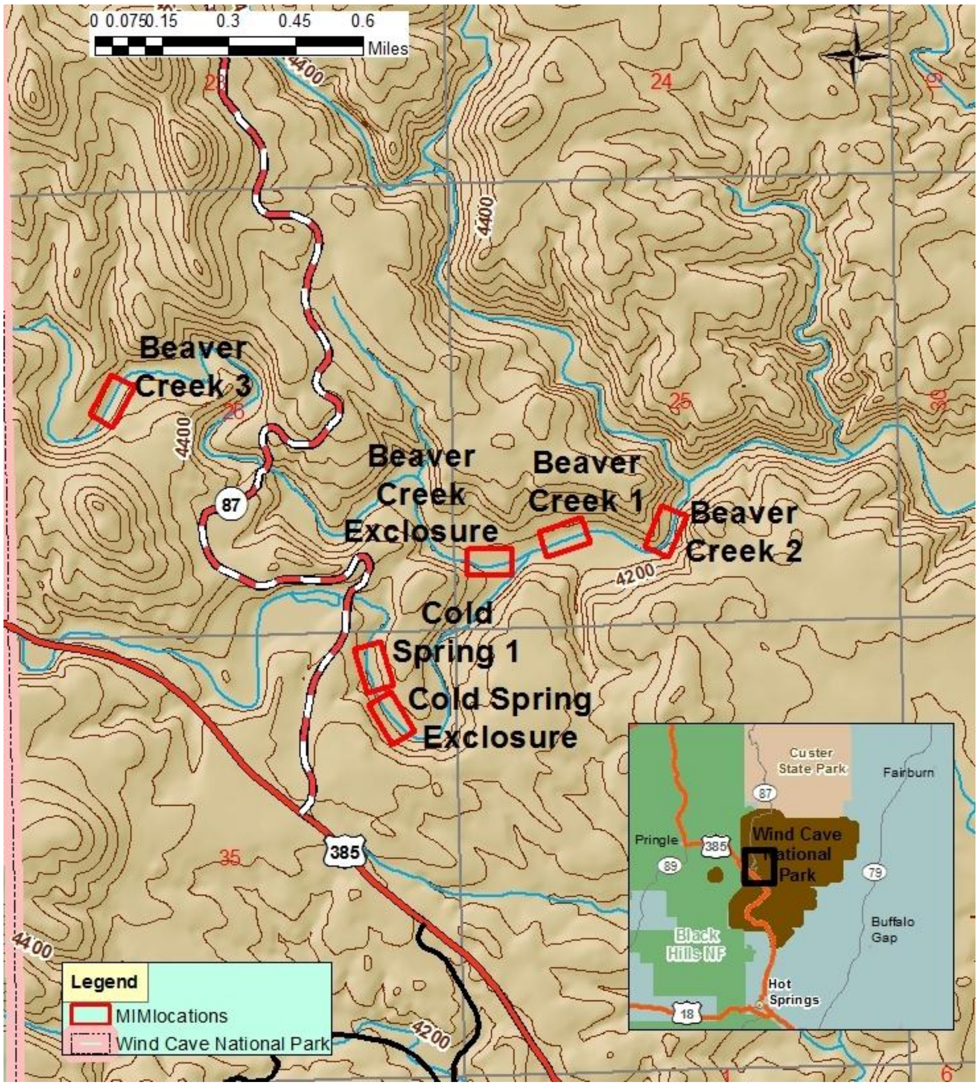


Figure 1. Locations of WICA DMAs on Beaver Creek and Cold Spring Creek.

Two representative DMAs (Highland Creek 1 and Highland Creek 2) and one reference DMA (Highland Creek Exclosure) were established on Highland Creek (Fig. 2).

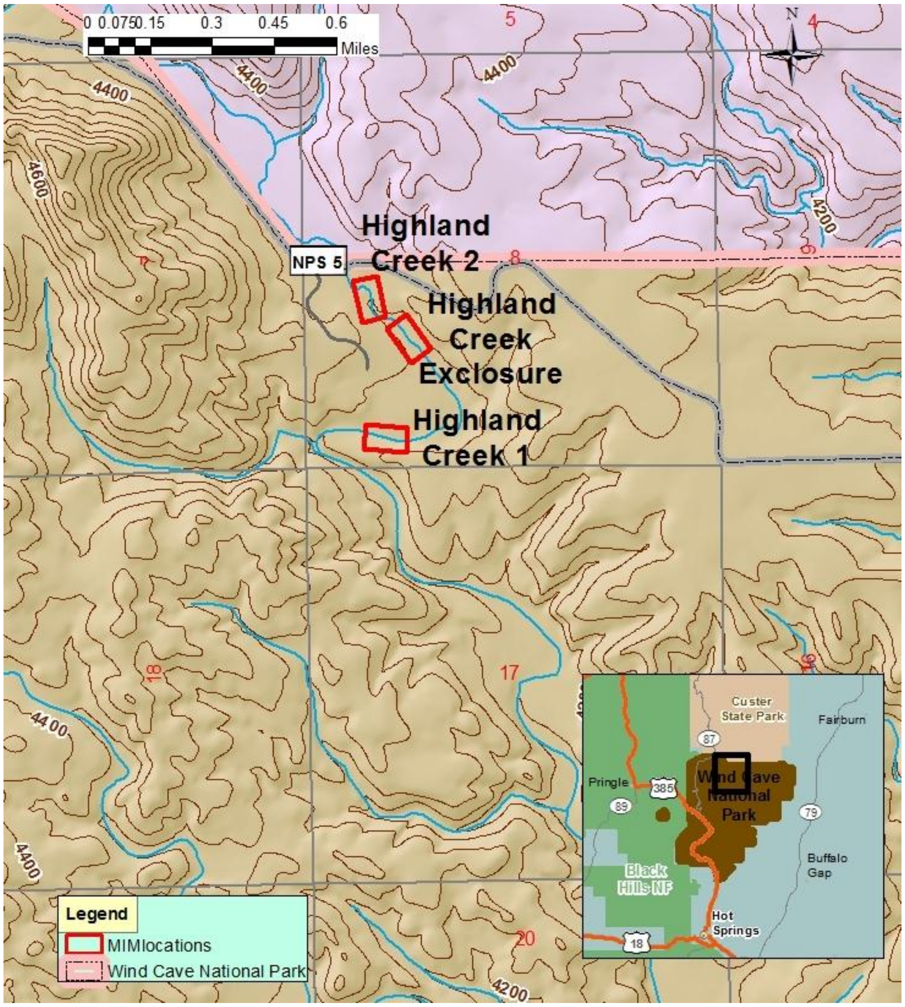


Figure 2. Locations of WICA DMAs on Highland Creek.

The representative DMAs on each stream were chosen to characterize different levels of wildlife/large herbivore utilization (high vs. moderate/low) in wide vs. narrow stream valleys. The reference DMAs are all in exclosures that were constructed in 1995 and in place for approximately 17 years. The exclosure reference condition is minimal wildlife use in a wide valley (note: elk can and occasionally do jump fences into exclosures so complete restriction of wildlife use is impossible). The use of this reference condition will provide insight into one of the major factors within management control that is influencing stream conditions in the park. Exclosure history is not well documented and fence maintenance is not highest priority, but wildlife has been restricted from streamside areas in exclosures for the majority of their existence. In 2012, bison breached the fence and intensively used Highland Creek Exclosure. Therefore, 2012 MIM data from Highland Creek Exclosure DMA was not used to reflect reference conditions.

DMA Layout and Indicator Measurement

The standard MIM DMA is 110 m long with 40 plots on each side of the stream (interval of 2.75 m between adjacent plots on the same side of the stream). All WICA DMAs outside exclosures are 110 m. WICA DMAs inside exclosures are the maximum length that could be accommodated (Table 1). Reducing the number of measurements generally increases confidence intervals on results. However, this effect was moderated by lower variability in exclosure measurements which decreases confidence intervals.

The MIM protocol includes procedures for monitoring 10 indicators. Three indicators provide data from which short-term livestock (or other large, hooved herbivore) use is quantified:

1. Stubble height [adapted from USDI BLM (1996b) and Challis Resource Area (1999)]
2. Streambank alteration (Cowley 2004)
3. Woody species use [adapted from USDI BLM (1996b)].

These indicators help determine whether the current season's/year's grazing is meeting grazing use criteria. They can be used as early warning indicators that current grazing impacts may prevent the achievement of management objectives and can also be used to help explain changes in riparian vegetation and channel conditions over time.

Seven indicators provide data for quantifying long-term resource condition:

1. Greenline composition (summarized by metrics including woody species composition, percent hydric herbaceous species, and plant diversity index) [adapted from Winward (2000) and USDI BLM (1996a)]
2. Woody species height class (Kershner et al. 2004)
3. Streambank stability [adapted from (Kershner et al. 2004)]
4. Streambank cover [adapted from (Kershner et al. 2004)]
5. Woody species age class [adapted from Winward (2000)]
6. Greenline-to-greenline width (Burton et al. 2008)
7. Substrate (Bunte and Abt 2001)

Long-term indicators are used to assess the current condition and trend of streambanks, channels, and streamside vegetation. They help determine if local grazing management strategies and other land management actions are making progress toward achieving the long-term goals and objectives for streamside riparian vegetation and aquatic resources.

Each indicator is briefly described in Table 2. For full detail including detailed application instructions, see BLM Technical Reference 1737-23 (Revised) which is available online at: http://www.blm.gov/nstc/library/pdf/MIM.pdf

Locating the greenline is key to using the MIM protocol since it is used as a reference point for collecting most of the sampling data. The "greenline" as defined by Winward (2000) is the "first perennial vegetation that forms a lineal grouping of community types on or near the water's edge." The greenline often coincides with the presence of water in the plant rooting zone, which allows for the growth of robust, hydrophytic plant species with deep roots that resist the erosive forces of the stream (Winward 2000). The greenline can be comprised of any combination of perennial herbaceous vegetation, shrub/tree seedlings, embedded rock, or anchored wood provided that there are no patches of bare ground (rocks smaller than 15 cm are considered bare ground), litter, or nonvascular plants greater than 10 cm by 10 cm within the plot.

Photographs were taken at the start of each DMA (downstream end looking upstream) for each monitoring event before taking MIM measurements, except for Beaver Creek 3 in 2009 (photograph was taken at upstream end of DMA looking downstream). Photographs were also taken throughout the DMAs during monitoring. Appendix A includes a start photograph and one within-DMA photograph for every monitoring event at WICA DMAs.

All indicators were measured in WICA DMAs for every monitoring period except substrate. The fine sediment component of the substrate in most DMAs was unexpectedly deep. MIM substrate measurements were made in 2009/2010 but only qualitative information was recorded in 2012.

Table 2. Descriptions of MIM indicators and importance relative to stream condition.

Indicator	Unit	Reference condition	Indicator Importance
Greenline composition	Percent cover of dominant and subdominant plant species, embedded rock, and anchored wood	High cover of deep, strong-rooted (native) vegetation on streambanks with appropriate contribution of anchored wood/embedded rock	High quality riparian vegetation is critically important for the stability of streambanks, streambank morphology (width, depth, and shape), water quality, and aquatic habitat quality. Greenline can also include embedded rock and/or anchored wood, which influences stream function and habitat quality.
Hydric herbaceous species	Percent of plots containing hydric (facultative wetland to obligate herbaceous) plant species	Moderate to high percentage of hydric plant species	Riparian-adapted vegetation is critically important for the stability of streambanks, stream morphology, water quality, and aquatic habitat quality.
Stubble height of dominant species	Height of plants after grazing (inches)	Generally, removal of no more than 50% of plants by weight occurs annually (riparian livestock use guidelines)	Foliar cover left after grazing and other disturbance is important to sustain plant health. Residual streambank vegetation helps maintain or promote strong root systems, protect streambanks from erosion, slow water during high stream flows, and build floodplains.
Streambank alteration	Percent of linear length of streambank altered by large herbivores during the current grazing season	Overall low to moderate percentage of altered streambanks (dynamic mosaic across the landscape may include areas of high percent altered banks)	Short-term indicator - heavily trampled streambanks are vulnerable to erosion and result in increased sediment supply to stream which may negatively affect water quality and damage aquatic habitat.
Streambank stability	Percent of linear length of streambank that is stable	High percentage of stable banks	Long-term indicator – due to unstable banks, water temperatures may increase; sediments are deposited in stream channel instead of on banks; streambank erosion increases; and water storage capacity of streambanks decreases – all resulting in loss of aquatic habitat.
Streambank cover	Percent of linear length of streambank with vegetation cover	High percentage of banks covered with strong, deep-rooted vegetation	Uncovered banks are unable to resist erosive effects of high stream flows - streamside vegetation may shift from hydric species to drier site species with low root density.

Table 2. Continued. Descriptions of MIM indicators and importance relative to stream condition.

Indicator	Unit	Reference condition	Indicator Importance
Greenline-to-greenline width (GGW)	The average non-vegetated distance between greenlines on each side of the stream (meters)	Stream channel not overly widened by herbivore trampling, with good integrity of streambanks	When protective vegetation is weakened or removed, sloping streambank profile can result. Subsequent erosion of weakened streambanks during floods results in wider, shallower stream channel profile which can be detrimental to aquatic species.
Woody species composition	Percent of plots containing woody plants	Woody species are present as appropriate to the potential of the riparian system	Healthy woody species provide strong, deep root systems that stabilize banks, filter sediment, provide shade, and provide habitat diversity.
Woody species use	Percent of current year's leaders on woody plants, shrubs and trees that are browsed	Woody species are present and browsing does not inhibit long-term woody species health	Short-term indicator of grazing utilization on woody species along streambanks. Healthy woody species provide strong, deep root systems that stabilize streambanks, shade streams, filter sediment, and provide habitat diversity.
Woody species height class	Height class of woody plant adjacent to stream	Multiple layers of woody plants occur along streambanks, appropriate to the plant community types present	Water temperature in streams (especially streams <10m wide) is directly affected by shading. Stream temperature determines the types, abundance, and distribution of aquatic organisms living in a stream.
Woody species age class	Estimate of age classes of woody species	Woody species are establishing along the streambank in balance with young, mature, and decadent plants	Long-term indicator of woody species health and persistence.
Substrate	Percent of substrate by size classes	Substrate sizes are variable and appropriate to stream type/geology	Channel instability often leads to channel widening, where energy balance shifts from erosion to deposition and fining of the substrate; increases in fines may degrade aquatic habitat.

A. Data Analysis

Data for WICA MIM project were collected using paper datasheets or Trimble Nomad with MIM 2008 Data Entry module loaded. All data were transferred/downloaded as appropriate to the MIM 2008 Data Entry Excel spreadsheets provided by the MIM protocol (available at: http://www.blm.gov/nstc/library/pdf/MIM.pdf). The MIM 2008 Data Analysis Module (also an Excel program) provided by the MIM protocol was used to import all of the raw data into data analysis spreadsheets, summarize the data, and calculate metrics useful for data interpretation. The MIM Data Analysis Module spreadsheets for all WICA DMAs in 2009, 2010, and 2012 are provided in Appendix B. The raw data in the MIM Data Entry spreadsheets are available in WICA-Resource Management files.

MIM analysis also includes metrics calculated based on indicator measurements. Four of them are used in WICA MIM analysis (Table 3):

1) Wetland Rating (Coles and Ritchie 2005) is a weighted number based on wetland indicator status (Lichvar 2012) of individual species based on their association with hydric (saturated) soils.

2) Winward Greenline Stability Rating (Winward 2000) is a determination of the relative ability of plant species in the DMA (or rock and wood) to withstand the erosive forces of water. Computations result in a weighted average for the DMA.
3) Greenline Ecological Status Rating (Winward 2000) is a determination of ecological status for the DMA using the weighted percentage of successional status of individual plant species along the greenline, as well as indicators of substrate, stream gradient, and presence/absence of woody vegetation.
4) Plant Diversity Index is calculated by multiplying the number of plant species by average species composition on the plots and dividing by the standard deviation of plant species composition. In WICA analysis, this metric was useful in comparisons between WICA DMAs but the range of values assigned in MIM analysis did not allow discrimination between WICA results (i.e., almost all WICA plant diversity indices were double or more the Very High category).

Table 3. MIM metrics used in WICA MIM analysis.

Metric	Rating Values	Metric Importance
Wetland Rating	0-15 Very poor 16-40 Poor 41-60 Fair 61-85 Good 85+ Very good	Presence of wetland plant species - wetland species are more functional in wetlands than upland species.
Winward Greenline Stability Rating	0-2 Very low 3-4 Low 5-6 Mid 7-8 High 9-10 Very high	Ability of greenline vegetation, anchored rock, and anchored wood to resist erosion.
Greenline Ecological Status Rating	0-15 Very early 16-40 Early 41-60 Mid 61-85 Late 85+ Potential natural community	Ecological status based on successional stage of plant species on the greenline, substrate, stream gradient, and presence/absence of woody vegetation.
Plant Diversity Index	<1 Very low 1-2 Low 3-4 Moderate 5-6 High >6 Very high	Plant diversity is important to ecologically sustainable vegetation, although the optimum in riparian systems may not be as high as in upland systems.

The 2013 MIM analysis spreadsheets calculate a 95% confidence interval (CI) around mean values based on standard deviation for measured indicators and a 95% CI based on observer variation for all indicators (measured and categorized). We used the larger CI to express uncertainty if there were two CIs for a given indicator/metric.

The MIM protocol acknowledges that monitoring results must be interpreted considering precision, accuracy, and ability to detect change for each monitoring indicator. MIM 2008 protocol used the coefficient of variation (CV) to determine acceptable level of precision (CV values <20 considered acceptable level of precision) and signal-to-noise ratio (S/N) to determine acceptable ability to detect change (S/N >10 indicates reasonably high detection capabilities). Refer to the MIM protocol (Burton et al. 2008) for CV and S/N discussions for each indicator and metric.

Extrapolation to Unsampled Stream Sections

In order to make an estimation of overall stream conditions for Beaver Creek and Highland Creek, we extrapolated results from sampled stream sections to larger stream segments by professional (but subjective) ground-based classification of unsampled stretches into stream condition complexes based on amount of wildlife use and geomorphology. WICA DMAs were originally chosen based on a stratification of wildlife use and geomorphology. After more experience with the areas after taking MIM measurements in 2009 – 2012 and additional evaluation on foot, the complexes were reviewed and considered appropriate for extrapolation of representative DMA data and results.

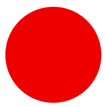
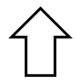
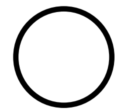
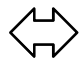
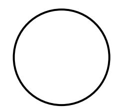
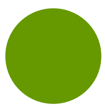
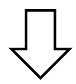
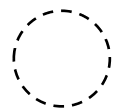
The length of Beaver Creek that had active surface water in 2009 and 2012 was from WICA west boundary to Beaver Creek sink, a distance of approximately 5400 meters (3.3 miles). The length of Highland Creek that had active surface water in 2009 and 2012 was from WICA north/Custer State park boundary to Highland Creek sink, a distance of approximately 2000 meters (1.2 miles). The Bison Corrals enclose ~500m of Highland Creek that has been highly altered by many years of human activity (including streambank modification) and bursts of concentrated use by wildlife related to roundups of bison and elk. We deemed this stretch not appropriate for MIM protocol application

Integrated Scores and Natural Resource Condition

All MIM indicators and metrics are considered together to develop an overall assessment for a stream's ecological condition as good, fair, or poor. We used professional judgment to make assessments of ecological condition which were reviewed for validity by MIM protocol author Ervin R. Cowley.

Results on DMA indicators, metrics, and stream condition assessments are summarized in Natural Resource Condition Tables based on the templates from the State of the Park report series (http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm). The goal of the Natural Resource Condition Table is to improve park priority settings and to synthesize and communicate complex park condition information to the public in a clear and simple way (Table 4). We decided MIM indicators and metrics with a majority of very poor/poor scores warranted natural resource condition ratings of Significant Concern, MIM indicators and metrics with a majority of fair scores warranted Caution ratings, and MIM indicators and metrics with a majority of good/very good scores warranted Good Condition ratings. Changes in indicators, metrics, and assessments from 2009/2010 to 2012 were represented as condition unchanging, improving, or deteriorating. The confidence in our conclusions from indicators, metrics, and assessment based on adherence to the MIM protocol and data/results review by Ervin R. Cowley is medium for all.

Table 4. Key to the symbols used in the Natural Resource Condition Table. The background color represents the current status, the arrow summarizes the change/trend, and the thickness of the outside line represents the degree of confidence in the assessment. A symbol that does not contain an arrow indicates that there is insufficient information to assess change/trend. Based on the State of the Park reports (http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm).

Status		**Change/Trend**		**Confidence**	
	Significant Concern		Condition is Improving		High
	Caution		Condition is Unchanging		Medium
	Good Condition		Condition is Deteriorating		Low

Results

Because precipitation has a large impact on stream flows as well as on stream lengths in WICA, where streams sink underground into porous limestone, we present annual precipitation values measured at the WICA visitor center (1.5 miles/2.4 km from Beaver and Cold Spring Creeks, 5.5 miles/8.9 km from Highland Creek) in Figure 3. Note that stream flow and length are influenced by varying lengths of time (i.e., not a single year; Driscoll and Carter 2001), but that below average precipitation in 2012 was reflected in lower stream flows and shorter stream lengths than in 2009/2010, when precipitation was above average (Figure 3).

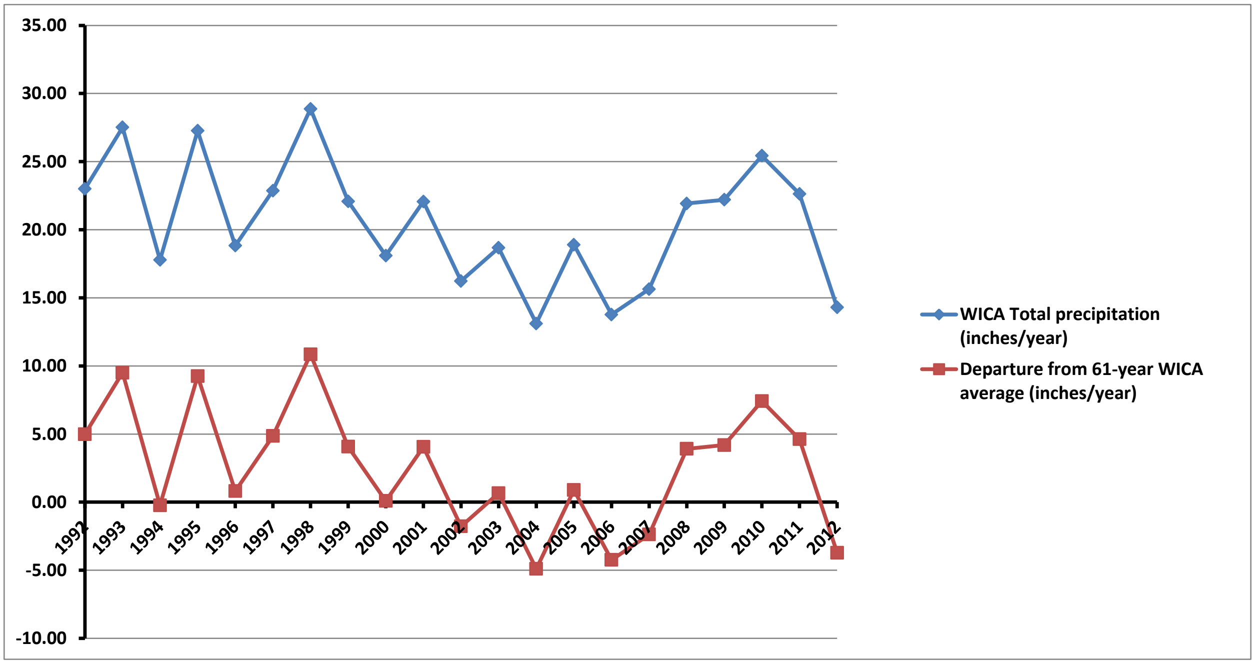


Figure 3. Annual precipitation data from WICA from 1992 to 2012 and departure of annual precipitation from 61-year WICA average (WICA climate station records).

In this section, the following are presented:

1) MIM data and analysis for <u>each DMA</u> – condition status and change assessed.
2) Consideration of MIM data from <u>all DMAs on a given stream</u> for condition and change.
3) MIM DMA data extrapolated to assess <u>overall stream condition and change</u> for Beaver Creek and Highland Creek (not Cold Spring Creek).

DMAs in exclosures were chosen to provide reference values and conditions for other DMAs on the same stream relative to wildlife/large herbivore use and geomorphology. The reference condition for wildlife/large herbivores is minimal use for the last 17 years (exclosures were constructed in 1995 as part of a vegetation/wildlife use investigation). Before that, for approximately 93 years since WICA was established, exclosure areas were managed without any distinction from adjacent areas. Two of the three reference DMAs occur in wide valleys and one occurs in a narrow valley. Geomorphology differences can contribute to vegetation differences (shaded, cooler stream reaches vs. sunny, warmer stream reaches) and patterns of wildlife use (by impacting accessibility and influencing wildlife concentration areas). It is important to note that reference conditions are not always equivalent to desired conditions. It is unlikely given WICA's enabling legislation to preserve native prairie wildlife that it will choose to manage to allow for no large herbivore use on WICA perennial streams. However, characterizing stream conditions with minimal large herbivore use is important and useful in understanding a full spectrum of wildlife use/effects.

The first choice data for reference values were the most recent exclosure DMA data from the same stream as the representative DMAs. However, in a few cases, other choices were made (all noted in the data tables). One case is dominant key species stubble height where the dominant key species was not the same in the reference and representative DMAs. Hydric species like Nebraska sedge (*Carex nebrascensis*) are very different from upland species like Kentucky bluegreass (*Poa pratensis*) and creeping bentgrass/redtop (*Agrostis stolonifera*) in characteristics from aboveground plant structure to root density to palatability. A grazed value for Nebraska sedge stubble height from a Beaver Creek DMA means little relative to an ungrazed reference value for Kentucky bluegrass in Beaver Creek Exclosure DMA. However, the ungrazed stubble height of Nebraska sedge in Highland Creek Exclosure DMA is a reasonable estimation of reference potential for Nebraska sedge elsewhere in WICA and was used for comparison.

A second case is Highland Creek Exclosure which was heavily grazed by bison in 2012 – hence, no longer in the reference condition of minimal wildlife use. 2010 Highland Creek Exclosure DMA data were used rather than 2012 Highland Creek Exclosure DMA data in reference comparisons with data from representative DMAs on Highland Creek. Thirdly, because sediment measurements were not made in 2012, 2009-2010 exclosure DMA sediment values were used as reference values for representative DMAs.

Table 5 provides a summary of all WICA DMAs for selected MIM indicators/metrics and results (without CIs).

Table 5. WICA DMA data for selected MIM parameters on Beaver Creek, Cold Spring Creek, and Highland Creek determined in 2009/2010 and 2012. See individual DMA results for data with confidence intervals. GGW = Greenline-to-greenline width.
Species codes: AGST2 = *Agrostis stolonifera* (creeping bentgrass/redtop); CANE = *Carex nebrascensis* (Nebraska sedge); CAREX = *Carex* species (sedge species); POPR = *Poa pratensis* (Kentucky bluegrass).

DMA_year	Mean stubble ht (in)	Covered bank (%)	Bank alteration (%)	Stable banks (%)	Mean GGW (m)	% Hydric herbaceous (%plots)	Woody Comp (%)	Ht of key dom sp (in)	Dom key sp for stubble ht	Plant diversity index	Windward Greenline Stability Rating	Site Wetland Rating	Greenline Ecological Status Rating
Beaver Creek 1_2009	4.2	4	82	0	5.43	56.5	2	3.9	CANE2	12.61	4.06 - Mid	63 - Good	13 - Very early
Beaver Creek 1_2012	3.0	3	92	0	4.85	51.5	1	2.7	CANE2	13.16	3.88 - Low	65 - Good	10 - Very early
Beaver Creek 2_2009	15.8	95	34	49	2.69	55.9	4	16.1	AGST2	14.92	4.87 - Mid	69 - Good	38 - Early
Beaver Creek 2_2012	20.7	73	68	0	2.58	57.7	1	18.3	AGST2	13.01	4.26 - Mid	74 - Good	33 - Early
Beaver Creek 3_2010	11.8	86	54	24	2.76	47.2	3	15.1	CAREX	14.71	4.43 - Mid	62 - Good	12 - Very early
Beaver Creek 3_2012	10.1	75	69	16	3.56	30.5	4	15.1	CAREX	18.91	3.51 - Low	52 - Fair	10 - Very early
Beaver Creek Excl._2009	16.5	90	1	79	2.61	45.8	19	14.6	POPR	9.39	3.01 - Low	43 - Fair	15 - Very early
Beaver Creek Excl._2012	16.2	100	6	87	2.44	36.8	10	13.2	AGST2	13.26	3.20 - Low	54 - Fair	7 - Very early
Highland Creek 1_2009	11.3	81	57	26	2.65	52.2	5	11.8	AGST2	18.48	4.49 - Mid	62 - Good	24 - Early
Highland Creek 1_2012	6.56	65	63	15	2.82	33.0	5	6.6	AGST2	19.08	3.7 - Low	52 - Fair	22 - Early
Highland Creek 2_2009	4.7	43	62	16	2.51	44.1	4	4.1	CANE2	22.72	4.57 - Mid	66 - Good	38 - Early
Highland Creek 2_2012	4.1	66	46	20	2.49	35.0	3	2.8	CANE2	15.42	3.98 - Low	58 - Fair	30 - Early
Highland Creek Excl._2010	20.0	100	0	95	2.74	51.7	15	22.2	CANE2	17.36	4.89 - Mid	58 - Fair	36 - Early
Highland Creek Excl._2012	5.4	45	90	3	2.77	49.6	9	4.4	CANE2	14.09	4.54 - Mid	60 - Fair	7 - Very early
Cold Springs 1_2010	9.7	44	79	8	4.97	23.5	10	7.2	CANE2	12.93	3.37 - Low	40 - Poor	23 - Early
Cold Springs Excl._2010	16.1	95	5	74	3.28	13.7	32	15.1	POPR	13.39	4.13 - Mid	31 - Poor	39 - Early

Data Interpretation by DMA

I. Beaver Creek Exclosure

Table 6 presents key indicators and metrics describing Beaver Creek Exclosure DMA. Highlights of analysis follow.

Table 6. Key indicators and metrics describing Beaver Creek Exclosure DMA condition in 2009 and 2012. Values represent means ± 95% CI. NA=Not available.

Metric	2009 Beaver Creek Exclosure	2012 Beaver Creek Exclosure	Reference	Beaver Creek Exclosure Condition
Mean stubble height (all key species)	16.5 ± 1.3 in	16.2 ± 1.5 in	NA	Low grazing supporting long-term plant health
Dominant key species – stubble height	Kentucky bluegrass 14.6 ± 1.0 in	Creeping bentgrass/redtop 13.2 ± 1.0 in	NA	Low grazing supporting undesirable key species
Plant diversity index	9.39	13.26	NA	Low-range among Beaver Creek DMAs
Hydric species (%plots)	45.8 ± 6.2%	36.8 ± 6.2%	NA	Low-range among Beaver Creek DMAs
Woody species composition	19 ± 6%	10 ± 6%	NA	Low contribution of woody species
Streambank cover	90 ± 5%	100 ± 5%	NA	Low grazing/disturbances contributing to high streambank cover
Stable banks	79 ± 5%	87 ± 5%	NA	Low trampling/disturbances contributing to high streambank stability
Bank alteration	1 ± 6%	6 ± 6%	NA	Low grazing resulting in low streambank alteration
Mean greenline-to-greenline width	2.61 ± 0.30 m	2.44 ± 0.30 m	NA	Mid-range among Beaver Creek DMAs
Substrate	68 ± 12% fines	No measurements made	NA	High fine sediment load contributing to high risk for aquatic habitat
Wetland rating	43 ± 5 - Fair	54 ± 5 - Fair	NA	Below average contribution by wetland species
Winward greenline stability rating	3.01 ± 0.16 - Low	3.20 ± 0.16 - Low	NA	Low resistance to erosion
Greenline ecological status rating	15 ± 5 – Very early	7 ± 5 – Very early	NA	Very early ecological condition is not resilient

Beaver Creek Exclosure parameters are useful in describing an area of low wildlife use for 17 years. There was no change in condition between 2009 and 2012 (indicator/metric differences were within confidence intervals). Stubble height is high relative to other DMAs; percent bank alteration is very low; percent covered banks is very high; percent stable banks is high.

However, high stubble height and low bank alteration indicators alone do not provide a complete condition assessment. In fact, high stubble height and low bank alteration often mask true conditions of exclosures (E. Cowley pers. comm. 2013). Beaver Creek Exclosure has a low percent hydric herbaceous species, low woody composition, and high percent fine substrate. Low percent hydric herbaceous species is paralleled with high percent cover of Kentucky bluegrass and creeping bentgrass/redtop on Beaver Creek Exclosure streambanks (captured as key dominant species). These non-native species can be aggressive in re-establishing on streambanks that developed a lower water storage capacity during previous periods of disturbance/grazing/trampling. The high sediment load observed indicates a high risk relative to ecological services supporting aquatic habitat.

Beaver Creek Exclosure metrics for wetland rating, Winward greenline rating, and greenline ecological status rating considered together indicate poor condition. This was not expected if recovery from pre-exclosure disturbance/wildlife use has been substantial. The data and analysis indicate that Beaver Creek Exclosure is not in a condition of resilient streambanks vegetated with high cover of perennial hydric species (including shrubs) with deep roots that stabilize banks and store water. Additional investigation is needed to determine whether native, hydric, woody, species are likely to become established in this exclosure.

Data support that Beaver Creek Exclosure DMA represents minimal wildlife use. Reconnaissance done for extrapolating condition assessments to unmeasured stretches suggests that the condition in Beaver Creek Exclosure is unique on Beaver Creek. Thus, for that extrapolation, the Beaver Creek Exclosure DMA is considered representative only of Beaver Creek Exclosure.

In summary, Beaver Creek Exclosure DMA with minimal wildlife utilization provides valuable conditions for comparison with other Beaver Creek DMAs undergoing greater wildlife use. However, it is a dynamic stream stretch itself that is still responding to exclusion of wildlife beginning 17 years ago. For almost one hundred years, management of Beaver Creek Exclosure was the same as management of other Beaver Creek DMAs (i.e., accessible by all the park's wildlife herds). Some attributes of streambanks and vegetation can change quickly (e.g., stubble height, streambank alterations) while others take much longer (e.g. percent hydric herbaceous species, plant species seral stage, woody species component) and/or require a much larger managed area upstream for change.

II. Beaver Creek 1

Table 7 presents key indicators and metrics describing Beaver Creek 1 DMA. Highlights of analysis follow.

Table 7. Key indicators of Beaver Creek 1 DMA condition in 2009 and 2012 and comparison to reference in Beaver Creek Exclosure DMA 2012 (except where noted: * = reference condition in Highland Creek Exclosure DMA 2010: **=reference condition in Beaver Creek Exclosure DMA 2009). Values represent means ± 95% CI.

Metric	2009 Beaver Creek 1	2012 Beaver Creek 1	Reference	Beaver Creek 1 Condition
Mean stubble height (all key species)	4.2 ± 1.0 in	3.0 ± 1.0 in	16.2 ± 1.5 in	High grazing not supporting long-term plant health
Dominant key species – stubble height	Nebraska sedge 3.9 ± 1.0 in	Nebraska sedge 2.7 ± 0.0 in	Nebraska sedge* 22.2 ± 2 in	High grazing not supporting long-term persistence of key species
Plant diversity index	12.61	13.16	13.26	Mid-range among Beaver Creek DMAs
Hydric species (%plots)	56.5 ± 6.2%	51.5 ± 6.2%	36.8 ± 6.2%	Mid-range among Beaver Creek DMAs
Woody species composition	2 ± 6%	1 ± 6%	10 ± 6%	Very low contribution of woody species
Streambank cover	4 ± 5%	3 ± 5%	100 ± 5%	High grazing/disturbances contributing to low streambank cover
Stable banks	0 ± 5%	0 ± 5%	87 ± 5%	High trampling/disturbances contributing to low streambank stability
Bank alteration	82%± 6	92%± 6	6 ± 6%	High trampling resulting in high streambank alteration
Mean greenline-to-greenline width	5.43 ± .38 m	4.85 ± .35 m	2.44 ± .30 m	Mid-range for all Beaver Creek DMAs
Substrate	Not measured – observation of fine sediment of 1 to 24 inches throughout DMA	Not measured – observation of fine sediment of 1 to 24 inches throughout DMA	68 ± 12% fines**	High fine sediment load contributing to high risk for aquatic habitat
Wetland rating	63 ± 5 - Good	65 ± 5 - Good	54 ± 5 - Fair	Average contribution by wetland species
Winward greenline stability rating	4.06 ± .16 - Mid	3.88 ± .16 - Low	3.20 ± .16 - Low	Low-mid resistance to erosion
Greenline ecological status rating	13 ± 6 – Very early	10 ± 6 – Very early	7 ± 5 – Very early	Very early ecological condition is not resilient

There was no change in condition in Beaver Creek 1 DMA between 2009 and 2012 (indicator/metric differences were within confidence intervals). MIM streamside vegetation parameters (mean stubble height, dominant key species, height of dominant key species, plant diversity index, percent hydric herbaceous species, woody species composition) for Beaver Creek 1 indicate that grazing of streamside vegetation was extreme. The ratio of mean stubble height in 2012 Beaver Creek 1 DMA (3 in) to mean stubble height in 2012 Beaver Creek Exclosure DMA (16.2 in) is 18.5%, indicating greater than 80% of plant material removed. This is not supportive of long-term plant health.

Nebraska sedge, a desirable native hydric species, was present in Beaver Creek 1 DMA and contributed to streambank stability. Nebraska sedge stubble height in Beaver Creek 1 DMA was compared to a reference of ungrazed Nebraska sedge stubble height in 2010 Highland Creek Exclosure DMA (Beaver Creek Exclosure DMA dominant stubble height species was an undesirable non-native species not appropriate for stubble height comparison). The ratio of stubble height of 3.9 in (2009) and 2.7 in (2012) for Nebraska sedge in Beaver Creek 1 DMA relative to the ungrazed mean Nebraska sedge stubble height of 22.2 in 2009 Highland Creek exclosure indicates a high level of grazing (ca 75%) that is not likely to support Nebraska sedge plant health in the long-term.

MIM bank parameters (percent streambank cover, percent bank alteration, percent stable bank, and mean greenline-togreenline width) for Beaver Creek 1 DMA indicate extremely unstable streambanks. No data points of stable banks were recorded either year; 3-4% covered streambanks were recorded; 82-92% bank alterations by current year hoof prints were recorded. The higher greenline-to-greenline width of Beaver Creek 1 DMA is likely a result of increased stream flow due to the input from Cold Spring Creek just west of the DMA. However, field observation also documented extensive bank area trampled to bare ground (see photographs in Appendix A).

Beaver Creek 1 DMA metrics for wetland rating, Winward greenline rating, and greenline ecological status rating considered together indicate poor condition. Plant species appropriate for a wetland are present, but erosional resistance is mid to low and ecological status is very early.

Data support that Beaver Creek 1 DMA represents heavy wildlife use. Reconnaissance done for extrapolating condition assessments to unmeasured stretches suggests that the condition of Beaver Creek upstream (west) of this DMA to Beaver Creek Exclosure and downstream (east) of this DMA to Beaver Creek 2 DMA is similar to that in the DMA: there are no physical barriers, the floodplain width and vegetation types are similar, level of wildlife use is high, etc. Thus, for that extrapolation, the Beaver Creek 1 DMA is considered representative of Beaver Creek stream conditions from Beaver Creek 1 DMA west to Beaver Creek Exclosure and east to Beaver Creek 2 DMA.

MIM protocol suggests estimating repair after disturbance by measuring both streambank alteration and streambank stability after the grazing period and then again just before the next grazing period. This is possible when examining impacts from livestock managed with on-off seasonality. There is no off-season in WICA for wildlife use of streams. Repair necessary to support healthy streambanks in WICA must occur through managing wildlife population sizes, protecting areas with exclosures, providing off-stream water sources, managing predators to discourage wildlife from lingering on streams, and/or other means.

Based on the 2009 and 2012 measurements, Beaver Creek 1 DMA is primarily providing one ecological service – water for wildlife. Although streamside stubble height was extremely low, rangelands/forage in adjacent stream terrace areas were not heavily grazed (B. Burkhart, pers. observations). Lower residual plant material would be expected if wildlife were focusing on this stream area for forage. This suggests that wildlife primarily utilize Beaver Creek 1 DMA for water rather than forage. Other ecological services besides water for wildlife (e.g., supporting diverse native streamside vegetation, providing water storage and resilient streambanks, and providing conditions to support aquatic life) are very minimally provided in Beaver Creek 1 DMA.

III. Beaver Creek 2

Table 8 presents key indicators and metrics describing Beaver Creek 2 DMA. Highlights of analysis follow.

Table 8. Key indicators of Beaver Creek 2 condition in 2009 and 2012 and comparison to reference in Beaver Creek Exclosure 2012 (except where noted: *=reference condition in Beaver Creek Exclosure 2009). Values represent means ± 95% CI. NA=not available.

Metric	2009 Beaver Creek 2	2012 Beaver Creek 2	Reference	Beaver Creek 2 Condition
Mean stubble height (all key species)	15.8 ± 1.2 in	20.7 ± 3.0 in	16.2 ± 1.5 in	Low grazing supporting long-term plant health
Dominant key species – stubble height	Creeping bentgrass/redtop 16.1 ± 2.0 in	Creeping bentgrass/redtop 18.3 ± 4.0 in	NA	Low grazing supporting long-term persistence of key species
Plant diversity index	14.92	13.01	13.26	Mid-range among Beaver Creek DMAs
Hydric species (%plots)	55.9 ± 6.2%	57.7 ± 6.2%	36.8 ± 6.2%	High-range among Beaver Creek DMAs
Woody species composition	4 ± 6%	1 ± 6%	10 ± 6	Very low contribution of woody species
Streambank cover	95 ± 5%	73 ± 5%	100 ± 5%	Increased trampling/disturbances contributing to lowered streambank cover
Stable banks	49 ± 5%	0 ± 5%	87 ± 5%	Increased trampling/disturbances contributing to lowered streambank stability
Bank alteration	34 ± 6%	68 ± 6%	6 ± 6%	Increased trampling resulting in high streambank alteration
Mean greenline-to-greenline width	2.69 ± 0.30 m	2.58 ± 0.30 m	2.44 ± .30 m	Mid-range among Beaver Creek DMAs
Substrate	Not measured – observation of fine sediment of 1 to 24 inches throughout DMA	No data	68 ± 12% fines*	High fine sediment load contributing to high risk for aquatic habitat
Wetland rating	69 ± 5 - Good	74 ± 4 - Good	54 ± 5 - Fair	Average contribution by wetland species
Winward greenline stability rating	4.87 ± .16 - Mid	4.26 ± .16 - Mid	3.20 ± .16 - Low	Mid resistance to erosion
Greenline ecological status rating	38 ± 6 – Early	33 ± 6 – Early	7 ± 5 – Very early	Early ecological condition is not resilient

Indicators of streambank alterations, percent streambank cover, and percent stable banks decreased significantly between 2009 and 2012. Because Beaver Creek 2 DMA was selected in 2009 to represent areas lightly utilized by wildlife, the result of at least moderate (e.g. bank alteration 34%; stable banks 49%) wildlife use in 2009 and high use in 2012 (bank alteration 68%; stable banks 0%) was unexpected. In addition, woody species composition is very low, plant diversity and percent hydric species are mid-range relative to all Beaver Creek DMAs, and stubble heights are high-range relative to all Beaver Creek DMAs (Table 5). However, creeping bentgrass/redtop is an undesirable dominant key species because it is non-native and generally a pioneer or invader species. It can rapidly establish and spread in overgrazed and otherwise disturbed sites previously dominated by native species. Its ability to withstand high levels of grazing makes replacement with former dominants difficult (Esser 1994).

Beaver Creek 2 metrics for wetland rating, Winward greenline rating, and greenline ecological status rating taken together indicate poor condition. Although plant species appropriate for a wetland are present, erosional resistance is only moderate and ecological status is early.

Beaver Creek 2 DMA is instructive in the kind of change that free-roaming wildlife can make in a short period of time as they react to their environment. It is likely that drier conditions in 2012 (Figure 3), which included complete dewatering of some stretches of Cold Spring Creek, concentrated wildlife on stretches of stream with water such as Beaver Creek 2. This was indicated by a measurable increase in streambank alterations and decrease in streambank stability. Dynamic wildlife use of perennial streams in WICA, in which higher use times are balanced by periods of lower use and recovery, is desirable. The challenge is to manage the system so that impacts do not preclude recovery and result in loss of desired ecosystem services.

Data on the vegetation parameters suggest that wildlife used the Beaver Creek 2 DMA area primarily for water rather than forage. This style of use (e.g. vegetation trampled but not grazed) decreases the stress on streambank plants relative to a style of use involving trampling and grazing. However, trampling alone over time can drastically alter streambanks and streamside vegetation and impact the ecosystem services the stream provides.

Data also suggest that Beaver Creek 2 DMA does not represent light wildlife use. Reconnaissance done for extrapolating condition assessments to unmeasured stretches suggests that condition of Beaver Creek downstream (east) of this DMA is similar to that in Beaver Creek 2 DMA: there are no physical barriers, the floodplain width and vegetation types are similar, wildlife use is similar, etc. Reconnaissance also suggests that condition of Beaver Creek between Beaver Creek Exclosure and Hwy 87 bridge over Beaver Creek is similar to that in Beaver Creek 2 DMA due to similarities in floodplain width, vegetation types, and wildlife use. Thus, for extrapolation purposes, Beaver Creek 2 DMA is considered representative of Beaver Creek streambank condition from Beaver Creek 2 DMA to the stream sink and between Beaver Creek Exclosure DMA and Hwy 87 bridge over Beaver Creek.

IV. Beaver Creek 3

Table 9 presents key indicators and metrics describing Beaver Creek 3 DMA. Highlights of analysis follow.

Table 9. Key indicators of Beaver Creek 3 condition in 2010 and 2012 and comparison to reference in Beaver Creek Exclosure 2012 (except where noted: *=reference condition in Beaver Creek Exclosure 2009). Values represent means ± 95% CI. NA=Not available.

Metric	2010 Beaver Creek 3	2012 Beaver Creek 3	Reference	Beaver Creek 3 Condition
Mean stubble height (all key species)	11.8 ± 1.4 in	10.0 ± 1.4 in	16.2 ± 1.5 in	Moderate grazing likely supporting long-term plant health
Dominant key species – stubble height	Sedge species 15.1 ± 2.0 in	Sedge species 15.1 ± 2.0 in	NA	Low grazing supporting long-term persistence of key species
Plant diversity index	14.71	18.91	13.26	Mid-range among Beaver Creek DMAs
Hydric species (%plots)	47.2 ± 6.2%	30.5 ± 6.2%	36.8 ± 6.2%	Mid-range among Beaver Creek DMAs
Woody species composition	3 ± 6%	4 ± 6%	10 ± 6%	Very low contribution of woody species
Streambank cover	86 ± 5%	75 ± 5%	100 ± 5%	Moderate grazing/disturbances contributing to moderate streambank cover
Stable banks	24 ± 5%	16 ± 5%	87 ± 5%	High trampling/disturbances contributing to low streambank stability
Bank alteration	54 ± 6%	69 ± 6%	6 ± 6%	High trampling resulting in high streambank alteration
Mean greenline-to-greenline width	2.76 ± 0.30 m	3.56 ± 0.30 m	2.44 ± 0.30 m	Mid-range for all Beaver Creek DMAs, increasing due to trampling/disturbances
Substrate	27 ± 12% fines	No data	68 ± 12% fines*	Low-range for all Beaver Creek DMAs; fine sediment load contributes to high risk for aquatic habitat
Wetland rating	62 ± 4 - Good	52 ± 5 - Fair	54 ± 5 - Fair	Average contribution by wetland species
Winward greenline stability rating	4.43 ± .16 - Mid	3.51 ± .16 - Low	3.20 ± .16 - Low	Mid resistance to erosion
Greenline ecological status rating	12 ± 6 – Very early	10 ± 6 – Very early	7 ± 5 – Very early	Very early ecological condition is not resilient

There was no significant change in conditions in Beaver Creek 3 DMA between 2009 and 2012 (indicator/metric differences were within confidence intervals or only slightly beyond). Because the Beaver Creek 3 DMA was selected in 2009 to represent areas lightly used by wildlife, the result of moderate to high wildlife use (e.g. bank alteration 54% and 69%; stable banks 24% and 16%) in 2010 and 2012 was unexpected. Plant diversity, stubble heights, key dominant species, and percent hydric species indicators are mid-range, and woody species composition is very low.

Beaver Creek 3 metrics for wetland rating, Winward greenline rating, and greenline ecological status rating taken together indicate poor condition. Species appropriate for a wetland are present, but erosional resistance is mid and ecological status is very early.

Vegetation parameter values for Beaver Creek DMA suggest that wildlife use of forage is moderate. Streambank parameter values suggest that wildlife use is high and primarily for water since streambank impacts are greater than expected for the level of forage removed. This style of use (involving trampling and grazing) without recovery periods can greatly alter streambanks and streamside vegetation and consequently alter the ecosystem services a stream provides. Beaver Creek 3 DMA had a much lower percentage of stable banks than expected considering it is in a narrow canyon that was hypothesized would not be attractive for utilization by large herds. It may be that Beaver Creek 3 area is less impacted by human activities, noise, etc. and some subset of the park's wildlife populations prefer that (i.e., large numbers in small groups still use the area, even if large herds do not). Beaver Creek 3 DMA was chosen, as Beaver Creek 2 DMA, to capture data from an area of light wildlife use. However, the results show that this area is moderately to highly used by wildlife.

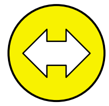
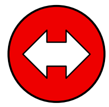
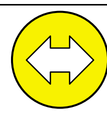
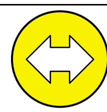
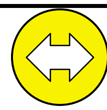
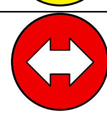
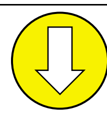
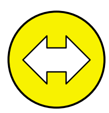
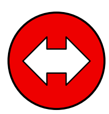
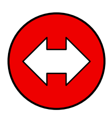
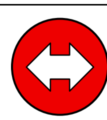
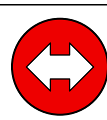
Data suggest that Beaver Creek 3 DMA does not represent light wildlife use. Reconnaissance done for extrapolating condition assessments to unmeasured stretches suggests that condition of Beaver Creek upstream (west) of this DMA is similar to that in Beaver Creek 3 DMA: there are no physical barriers, the floodplain width and vegetation types are similar, and wildlife use is moderate to high. Thus, for that extrapolation, Beaver Creek 3 DMA is considered representative of Beaver Creek stream condition from Beaver Creek 3 DMA west to the WICA boundary.

Beaver Creek Discussion (Considering All Beaver Creek DMAs)

A goal of this project was to characterize the range of streambank and streamside vegetation conditions on Beaver Creek through distribution of an achievable number of MIM DMAs. DMA locations were chosen with the intent of representing minimal wildlife use (reference condition), high wildlife use, and light-to-moderate wildlife use in wide and narrow valleys. The results indicate that the project was successful in characterizing minimal wildlife use and high wildlife use areas on Beaver Creek. However, both DMAs selected for representing light to moderate wildlife use instead had characteristics more consistent with moderate to high wildlife use. Based on field reconnaissance of the entire length of Beaver Creek, it is unlikely that there are any stretches of Beaver Creek at this time that would fit the category of light wildlife use. Establishment of additional DMAs could provide data to evaluate this conclusion.

A summary of condition status and change from 2009 to 2012 for WICA DMAs on Beaver Creek is provided in Table 10.

Table 10. Summary of condition status and change from 2009 to 2012 for DMAs on Beaver Creek. See Table 4 for explanation of symbols.

Indicator of Condition	Stream DMA	Condition Status/Change	MIM Parameters Evaluated
Streamside vegetation	**Beaver Creek Exclosure**		Mean stubble height of all species; Mean stubble height of dominant species; Mean greenline-to-greenline width; Plant diversity index; Percent hydric species; Woody composition
	Beaver Creek-1		
	Beaver Creek-2		
	Beaver Creek-3		
Streambank stability	**Beaver Creek Exclosure**		Percent bank alteration; Percent covered banks; Percent stable banks; Mean greenline-to-greenline width
	Beaver Creek-1		
	Beaver Creek-2		
	Beaver Creek-3		
Ecological condition	**Beaver Creek Exclosure**		Wetland rating; Winward greenline stability rating; Greenline ecological status rating
	Beaver Creek-1		
	Beaver Creek-2		
	Beaver Creek-3		

Beaver Creek Exclosure DMA appeared to be in good condition for streamside vegetation and streambank stability resulting from minimal wildlife use, but short-term indicators of stubble height and alterations were outweighed by long-term indicators of plant wetland status, vegetation seral stage, substrate, and absence of woody species. Stubble height and lack of alterations often mask other indicators in exclosures (E. Cowley pers. comm. 2013). The overall condition of streambanks and streamside vegetation in Beaver Creek Exclosure DMA was poor and stable from 2009 to 2012.

Beaver Creek Exclosure DMA provides information on initial development (17 years) of a reference condition for minimal wildlife grazing on Beaver Creek. No or minimal wildlife grazing is not a likely desired condition for every segment of Beaver Creek. However, a well-developed reference condition is important to understand impacts of a primary disturbance that management can control or influence - wildlife grazing. It is critical that Beaver Creek Exclosure fence be maintained to effectively and consistently restrict wildlife so investigation into this reference condition can continue.

Beaver Creek 1, Beaver Creek 2, and Beaver Creek 3 DMAs are overall in poor condition. The areas display slightly different characteristics of streambank and streamside vegetation condition that likely result in slightly different provision of ecological services. These details were not discerned in this study.

Taking measurements for the substrate indicator was problematic. The fine sediment load observed in all Beaver Creek DMAs was unexpectedly high. More research on sediment loads for streams similar to WICA perennial streams would be useful. However, the high sediment load observed is a flag for high risk relative to ecological services that support aquatic habitat.

Beaver Creek 1, 2, and 3 DMAs do not support a diversity of riparian/streamside vegetation needed to support other riparian/streamside and aquatic life such as insects, snakes, frogs, and minnows. The streambanks and streamside vegetation have a low ability to store water. Banks are losing sediment to Beaver Creek and will not be able to buffer high stream flows. Future low precipitation or drought will likely allow further deterioration in the condition of streambanks and streamside vegetation if wildlife use continues to be concentrated in areas with available water. Currently, Beaver Creek 1, Beaver Creek 2, and Beaver Creek 3 DMAs are providing the ecological service of water for wildlife but do not have streambank, streamside vegetation, and ecological characteristics that would allow them to provide other ecological services. All Beaver Creek DMAs are better characterized as vulnerable rather than resilient to future stresses.

Data collected for this project are applicable to the sampled areas and to the complexes that representative DMAs were chosen to represent. These areas were determined during DMA establishment in 2009/2010 and additional reconnaissance in 2012.

The conclusions of this project are (Table 11):
1) Beaver Creek Exclosure DMA provides data on a reference condition of minimal wildlife use/wide valley since exclosure construction in 1995 and characterizes only Beaver Creek within the exclosure. Based on observation, no other segments of Beaver Creek appear

similar to the area in the exclosure. Beaver Creek Exclosure DMA is representative of 0.02% of Beaver Creek.

2) Beaver Creek 1 DMA is representative of Beaver Creek from Beaver Creek Exclosure DMA to Beaver Creek 2 DMA or 11% of Beaver Creek.
3) Beaver Creek 2 DMA is representative of Beaver Creek from Beaver Creek 2 DMA east to Beaver Creek sink. Beaver Creek 2 DMA is also representative of Beaver Creek from the Hwy 87 High Bridge to Beaver Creek Exclosure DMA. Total length of both segments is 46% of Beaver Creek.
4) Beaver Creek 3 DMA is representative of Beaver Creek from the west park boundary to Hwy 87 High Bridge or 43% of Beaver Creek.

Table 11. Complexes of Beaver Creek determined in 2009 and further evaluated in 2012 for similarity of streambanks and streamside vegetation. NA=Not available.

Stream complex	Length	Approximate percent of stream	Representative DMA
TOTAL Beaver Creek length (West boundary to Beaver Creek sink)	5400 meters (3.3 miles)	100%	NA
Segment: West boundary to Hwy 87 High Bridge	2300 meters	43%	Beaver Creek 3
Segment: Hwy 87 High Bridge to Beaver Creek Exclosure	1200 meters	23%	Beaver Creek 2
Segment: Beaver Creek exclosure	100 meters	.02%	Beaver Creek Exclosure
Segment: Exclosure to Beaver Creek 2 DMA	600 meters	11%	Beaver Creek 1
Segment: Beaver Creek 2 DMA to sink	1200 meters	23%	Beaver Creek 2

At the beginning of the project, it was expected that different condition ratings would be developed from different DMAs and extrapolated to similar complex areas. However, all Beaver Creek DMAs were rated the same - overall in poor condition. Thus, the conclusion is that 100% of Beaver Creek is in poor condition. This means Beaver Creek is not able to provide a wide range of ecological services and is at risk for further reduction in the ecological services it provides. The risk is increased by factors such as drought and high wildlife/large herbivore numbers. Establishing more DMAs would allow results to be more defensibly applicable to the whole stream. This would also assist staff in evaluating whether management actions taken are achieving desired results. However, continuing to collect MIM data in existing DMAs alone will still allow evaluation of Beaver Creek condition status and change.

It was expected that there would be segments of Beaver Creek that wildlife rarely used – that might provide refugia for riparian plant species sensitive to grazing and trampling disturbances. However, this was not supported by DMA data or full stream reconnaissance. Consequently, determining exactly what constitutes reference condition is extremely difficult. The nature of NPS mission (to conserve natural resources unimpaired for future generations) makes it likely to assume that high quality riparian condition would be achievable in the park (as it is for high quality upland condition). If this is not the case, perhaps stream stretches in MIM high quality condition exist on other public or private lands in the Black Hills. Black Hills National Forest has established DMAs and collected MIM data on some streams in the Black Hills, as has a citizen Black Hills MIM Project. Results of from these efforts are just beginning to become available and will provide a useful context for WICA MIM results. If MIM high quality condition streams cannot be found in the Black Hills but are still considered achievable, then standards and guidelines for range/ecology management, national forest/grassland management, national park system management, etc. and their implementation effectiveness are in need of review.

It is worth noting that some vegetation parameters are easily changed/improved. For example, a year of high precipitation alone can increase plant production and result in higher stubble heights, with no management changes at all. On the other hand, improvement in some bank parameters, such as stable banks and sediment load, may require many years (with or without management changes) to recover from just one or a few years of high bank alterations. It takes a number of parameters functioning over different time scales to fully describe streambank/vegetation condition, to document short-term and long-term changes, and to understand ecological condition.

A primary purpose of this study was to provide information that would be able to serve as a foundation for management discussions on Beaver Creek. It is very important to overall Beaver Creek ecological services that current conditions for all segments be understood, desired conditions prioritized, management tools affecting condition identified, and monitoring conducted appropriately to inform management choices and determine results.

V. Highland Creek Exclosure

Table 12 presents key indicators and metrics describing Highland Creek Exclosure DMA. Highlights of analysis follow.

Table 12. Key indicators of Highland Creek Exclosure condition in 2010 and 2012 (bison accessed exclosure). Values represent means ± 95% CI.

Metric	2010 Highland Creek Exclosure	2012 (bison access) Highland Creek Exclosure	Reference	2010 Highland Creek Exclosure Condition
Mean stubble height (all key species)	20.0 ± 2.0 in	5.4 ± 0.1 in	2010	Low grazing supporting long-term plant health
Dominant key species – stubble height	Nebraska sedge 22.1 ± 2.0 in	Nebraska sedge 4.4 ± 1.0 in	2010	Low grazing supporting long-term persistence of key species
Plant diversity index	17.36	14.09	2010	Mid-range among Highland Creek DMAs
Hydric species (%plots)	51.7 ± 6.2%	49.6 ± 6.2%	2010	Mid-range among Highland Creek DMAs
Woody species composition	15 ± 6%	9 ± 6%	2010	Low contribution of woody species
Streambank cover	100 ± 5%	45 ± 5%	2010	Low grazing/disturbances contributing to high streambank cover
Stable banks	95 ± 5%	3 ± 5%	2010	Low trampling/disturbances contributing to high streambank stability
Bank alteration	0 ± 6%	90 ± 6%	2010	Low grazing resulting in low streambank alteration
Mean greenline-to-greenline width	2.74 ± .37 m	2.77 ± .36 m	2010	Mid-range among Highland Creek DMAs
Substrate	59 ± 12% fines	no measurements	2010	High fine sediment load contributing to high risk for aquatic habitat
Wetland rating	58 ± 5 - Fair	60 ± 5 - Fair	2010	Below average contribution by wetland species
Winward greenline stability rating	4.89 ± .16 - Mid	4.54 ± .16 - Mid	2010	Mid resistance to erosion
Greenline ecological status rating	36 ± 6 – Early	7 ± 6 – Very early	2010	Early ecological condition is not resilient

2010 Highland Creek Exclosure DMA parameters (before wildlife access/use in 2012) are useful in describing an area of low wildlife utilization for 17 years. 2012 Highland Creek Exclosure short-term indicators reflect that many bison accessed and utilized the area in summer 2012. This prevents the use of 2012 Highland Creek Exclosure DMA data for description of ongoing reference condition on Highland Creek. However, they will be useful as baseline for studying streamside vegetation and streambank response in Highland Creek Exclosure following one year of intensive bison use.

There were large changes in short-term indicators between 2010 and 2012 but very little change in long-term indicators. 2010 Highland Creek Exclosure DMA stubble height is high relative to utilized areas; percent bank alteration is very low; percent covered banks is very high; and percent stable banks is high. However, high stubble height and low bank alteration indicators alone do not provide a complete condition assessment. In fact, high stubble height and low bank alteration often mask true conditions in exclosures (Cowley pers. comm. 2013).

Highland Creek Exclosure DMA has a moderate percent hydric herbaceous species, low woody composition, and high percent fine substrate. Nebraska sedge, a desirable native hydric species, was present in Highland Creek Exclosure to contribute to streambank stability.

Highland Creek Exclosure DMA metrics for wetland rating, Winward greenline rating, and greenline ecological status rating indicate poor condition. This is not expected if recovery from pre-exclosure disturbance/wildlife use has been substantial. The data and analysis indicate that even before bison access in 2012, Highland Creek Exclosure was not restored to a condition of resilient streambanks vegetated with high cover of perennial hydric species (including shrubs) that have deep roots which stabilize banks and store water. Additional investigation is needed to determine whether native, hydric, woody, species are likely to become established in this exclosure.

Taking measurements for the substrate indicator was problematic. The fine sediment load observed in Highland Creek Exclosure DMA (and all Highland Creek DMAs) was unexpectedly high. More research on sediment loads for streams similar to WICA perennial streams would be useful. However, the high sediment load observed is a flag for high risk relative to ecological services that support aquatic habitat.

In summary, Highland Creek Exclosure DMA with minimal wildlife utilization (2010) provides valuable conditions for comparison with other Highland Creek DMAs in areas undergoing greater wildlife utilization. However, it is a dynamic stream stretch itself that is still responding to exclusion of wildlife beginning 17 years ago. For almost one hundred years, management of Highland Creek Exclosure DMA was the same as management of other Highland Creek DMAs (i.e., accessible by all the park’s wildlife herds). Unplanned bison use of Highland Creek Exclosure DMA in 2012 demonstrated that some attributes of streambanks and vegetation in Highland Creek Exclosure DMA can change quickly (e.g., stubble height, streambank alterations) while others take much longer (e.g. percent hydric herbaceous species, plant species seral stage, woody species component).

VI. Highland Creek 1

Table 13 presents key indicators and metrics describing Highland Creek 1 DMA. Highlights of analysis follow.

Table 13. Key indicators of Highland Creek 1 condition in 2009 and 2012 and comparison to reference in Highland Creek Exclosure 2010. Values represent means ± 95% CI. NA=not available

Metric	2009 Highland Creek 1	2012 Highland Creek 1	Reference	Highland Creek 1 Condition
Mean stubble height (all key species)	11.3 ± 1.0 in	6.6 ± 1.0 in	20 ± 2 in	Moderate grazing likely supporting long-term plant health
Dominant key species – stubble height	Creeping bentgrass/redtop 11.8 ± 2.0 in	Creeping bentgrass/redtop 6.6 ± 1.0 in	Nebraska sedge 22.2 ± 2.0 in	Moderate grazing likely supporting undesirable key species
Plant diversity index	18.48	19.08	17.36	Mid-range for all Highland Creek DMAs
Hydric species (%plots)	52.2 ± 6.2%	33 ± 6.2%	51.7 ± 6.2%	Mid-range for all Highland Creek DMAs
Woody species composition	5 ± 6%	5 ± 6%	15 + 6%	Very low contribution of woody species
Streambank cover	81 ± 5%	65 ± 5%	100 ± 5%	Moderate grazing contributing to lower streambank cover
Stable banks	26 ± 5%	15 ± 5%	95 ± 5%	High trampling/disturbances contributing to low streambank stability
Bank alteration	57 ± 6%	63 ± 6%	90 ± 6%	High trampling resulting in high streambank alteration
Mean greenline-to-greenline width	2.65 ± 0.30 m	2.82 ± 0.30 m	2.74 ± .37 m	Mid-range for all Highland Creek DMAs
Substrate	37 + 12% fines	No data	59 ± 12% fines	Fine sediment load contributing to high risk for aquatic habitat
Wetland rating	62 ± 4.2 - Good	52 ± 4.7 - Fair	58 ± 5.5 - Fair	Below average contribution by wetland species
Winward greenline stability rating	4.49 ± 0.16 - Mid	3.7 ± 5.5 - Low	4.89 ± 0.16 - Mid	Mid-low resistance to erosion
Greenline ecological status rating	24 ± 6 – Early	22 ± 6 – Early	36 ± 6 – Early	Early ecological condition is not resilient

Based on field observation, Highland Creek 1 DMA was selected to characterize light utilization by wildlife. It was unexpected that data on MIM bank parameters would support that wildlife utilization was high. The data on some vegetation parameters for Highland Creek 1 DMA (moderate stubble height for all key species and dominant key species) indicate that streamside vegetation was used but not heavily used. Covered banks decreased but bank alterations did not change from 2009 to 2012. Wildlife use of Highland Creek 1 DMA appears to be more for water rather than forage. This style of use (e.g. more vegetation trampled than grazed/removed) decreases the stress on streambank plants relative to a style of use involving trampling and grazing. However, trampling alone over time can greatly alter a stream and affect the ecosystem services it can provide.

The designation of non-native, non-hydric creeping bentgrass/redtop as a dominant key species is a signal of undesirable vegetation condition in Highland Creek 1 DMA. Upland species may have a greater contribution to the vegetation of this stretch of Highland Creek because Highland Creek has been documented over time to sink in various locations upstream of Highland Creek 1 DMA. In seasons and years where Highland Creek 1 DMA has no stream flow, Great Plains upland species are able to displace hydric species – and several non-native species including creeping bentgrass/redtop and Kentucky bluegrass may be aggressive and competitive in this situation. The lower percent hydric herbaceous species in Highland Creek 1 DMA is consistent with a high percent cover of creeping bentgrass/redtop on streambanks.

Highland Creek 1 DMA metrics for wetland rating, Winward greenline rating, and greenline ecological status rating considered together indicate poor condition. Plant species appropriate for a wetland are present, but erosional resistance is mid to low and ecological status is early.

Data support that Highland Creek 1 DMA represents heavy wildlife use rather than light wildlife use. Drier conditions/less precipitation in 2012 (Figure 3) caused area springs and ephemeral streams to dry up which may have contributed to concentrating more wildlife on persistent perennial streams including Highland Creek. Reconnaissance done for extrapolating condition assessments to unmeasured stretches suggests that the condition of Highland Creek downstream (south) of Highland Creek 1 DMA to Highland Creek sink is similar to that in Highland Creek 1 DMA: there are no physical barriers, the floodplain width and vegetation types are similar, and level of wildlife use is similar. Thus, for that extrapolation, the Highland Creek 1 DMA is considered representative of Highland Creek stream conditions from Highland Creek 1 DMA south to Highland Creek sink.

VII. Highland Creek 2

Table 14 presents key indicators and metrics describing Highland Creek 2 DMA. Highlights of analysis follow.

Table 14. Key indicators of Highland Creek 2 condition in 2009 and 2012 and comparison to reference in Highland Creek Exclosure 2010. Values represent means ± 95% CI. NA=not available

Metric	2009 Highland Creek 2	2012 Highland Creek 2	Reference	Highland Creek 2 Condition
Mean stubble height (all key species)	4.7 ± 1.0 in	4.1 ± 1.0 in	20 ± 2 in	High grazing not supporting long-term plant health
Dominant key species – stubble height	Nebraska sedge 4.1 ± 1.0 in	Nebraska sedge 2.8 ± 1.0 in	Nebraska sedge 22.2 ± 2.0 in	High grazing not supporting long-term persistence of key species
Plant diversity index	22.72	15.42	17.36	Mid-range for all Highland Creek DMAs
Woody species composition	4 ± 6%	3 ± 6%	15 ± 6%	Very low contribution of woody species
Streambank cover	43 ± 5%	66 ± 5%	100 ± 5%	High grazing contributing to low streambank cover
Stable banks	16 ± 5%	20 ± 5%	95 ± 5%	High trampling/disturbances contributing to low streambank stability
Bank alteration	62 ± 6%	46 ± 6%	90 ± 6%	High trampling resulting in high streambank alteration
Mean greenline-to-greenline width	2.51 ± 0.30 m	2.49 ± 0.30 m	2.74 ± .37 m	Mid-range for all Highland Creek DMAs
Substrate	26 ± 12% fines	No data	59 ± 12% fines	Fine sediment load contributing to high risk for aquatic habitat
Wetland rating	66 ± 4 - Good	58 ± 4 - Fair	58 ± 5 - Fair	Below average contribution by wetland species
Winward greenline stability rating	4.57 ± .16 - Mid	3.98 ± .16 - Low	4.89 ± .16 - Mid	Mid-low resistance to erosion
Greenline ecological status rating	38 ± 6 – Early	30 ± 6– Early	36 ± 6 – Early	Early ecological condition is not resilient

There was no change from 2009 to 2012 on most short-term indicators in Highland Creek 2 DMA. Highland Creek 2 DMA attributes indicate high use by wildlife. Streambank parameters showed high levels of bank alteration, low percent covered banks and low percent stable banks. Vegetation parameters showed low mean stubble height of all key species (~24%) and of dominant key species Nebraska sedge (~15%) relative to Highland Creek Exclosure 2009, demonstrating 75 to 85% removal of plant material. This indicates significant use of the area by wildlife for forage and greater removal of plant material than can sustain healthy plant persistence. Highland Creek 2 DMA is bordered by a prairie dog town where vegetation was observed to be clipped and sparse in 2009 and 2012. At some monitoring points, a greenline could not be found when streambank vegetation did not meet percent cover requirements and upland vegetation beyond was also too sparse. Percent hydric species and plant diversity index were similar to all other Highland Creek DMAs.

The percent fines measured for Highland Creek 2 DMA in 2010 were significantly less than the percent fines measured for Highland Creek Exclosure DMA in 2010 but best interpretation of the data is unclear. Highland Creek 2 DMA was the most amenable to substrate data collection and substrate data could be valuable in characterizing the stream's qualities relative to fishery habitat (note: Highland Creek currently supports (and has supported in the past) a small population of non-native brook trout in this area). In 2012, no quantitative substrate measurements were made. More research into substrate conditions on similar streams would be useful for interpretation of WICA data. However, the sediment load is a flag for high risk relative to ecological services that support aquatic habitat.

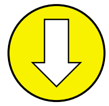
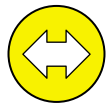
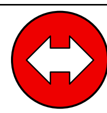
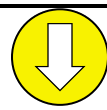
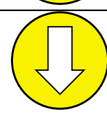
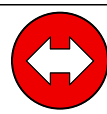
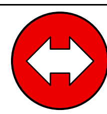
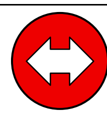
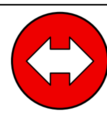
Highland Creek 1 DMA long-term metrics for wetland rating, Winward greenline rating, and greenline ecological status rating considered together indicate poor condition and no change from 2009 to 2012. Plant species appropriate for a wetland are present, but erosional resistance is mid to low and ecological status is early.

Highland Creek Discussion (Considering All Highland Creek DMAs)

A goal of this project was to characterize the range of streambank and streamside vegetation conditions on Highland Creek through distribution of an achievable number of DMAs. DMAs were chosen based on field observation to cover minimal wildlife use (reference condition), high wildlife use, and light-to-moderate wildlife use. MIM data results indicate that the project was successful in characterizing minimal wildlife use and high wildlife use areas on Highland Creek. However, the DMA selected to represent light to moderate wildlife use provided results that indicate moderate to high wildlife use. Based on field reconnaissance of the entire length of Highland Creek, it is unlikely that there are any stretches of Highland Creek at this time that would fit the category of light wildlife use. Establishment of additional DMAs could provide data to further investigate.

A summary of condition status and change from 2009 to 2012 for streambank stability, streamside vegetation, and ecological condition in DMAs on Highland Creek is provided in Table 15.

Table 15. Summary of condition status and change from 2009 to 2012 for DMAs on Highland Creek. See Table 4 for explanation of symbols.

Indicator of Condition	Stream DMA	Condition Status/Change	MIM Parameters Evaluated
Streamside vegetation	**Highland Creek Exclosure**		Mean stubble height of all species; Mean stubble height of dominant species; Mean greenline-to-greenline width; Plant diversity index; Percent hydric species
	Highland Creek-1		
	Highland Creek-2		
Streambank stability	**Highland Creek Exclosure**		Percent bank alteration; Percent covered banks; Percent stable banks; Mean greenline-to-greenline width
	Highland Creek-1		
	Highland Creek-2		
Ecological condition	**Highland Creek Exclosure**		Wetland rating; Winward greenline stability rating; Greenline ecological status rating
	Highland Creek-1		
	Highland Creek-2		

Highland Creek Exclosure DMA appeared to be in fair condition of streamside vegetation and streambank stability (decrease in condition from 2010 to 2012 primarily because bison accessed the exclosure in 2012 and heavily used the stream and streambank areas) but short-term indicators of stubble height and streambank alterations were outweighed by long-term indicators of plant wetland status, vegetation seral stage, substrate, and absence of woody species. Stubble height and lack of alterations often mask other indicators in exclosures (E. Cowley pers. comm. 2013). The overall vulnerable condition of streambanks/streamside vegetation and poor ecological condition in Highland Creek Exclosure DMA was stable from 2009 to 2012.

Highland Creek Exclosure DMA provides information on the beginning (17 years) of a reference condition for minimal wildlife grazing/wide valley on Highland Creek. Highland Creek Exclosure DMA overall is in poor ecological condition and there was no change from 2009 to 2012. No/minimal wildlife grazing is not a likely desired condition for every segment of

Highland Creek. However, a well-developed reference condition is important to understand impacts of a primary disturbance that management can control or influence - wildlife grazing. It is critical that Highland Creek Exclosure fence be maintained to effectively and consistently restrict wildlife to allow for continued investigation into the reference condition of minimal wildlife grazing.

Highland Creek 1 DMA and Highland Creek 2 DMA are overall in poor condition. The areas display slightly different characteristics of streambank and streamside vegetation condition that likely result in slightly different provision of ecological services. These details were not discerned in this study.

Taking measurements for the substrate indicator was problematic. The fine sediment load observed in all Highland Creek DMAs was unexpectedly high. More research on sediment loads for streams similar to WICA perennial streams would be useful. However, the high sediment load observed is a flag for high risk relative to ecological services that support aquatic habitat.

Highland Creek DMAs do not support a diversity of riparian/streamside vegetation needed to support other riparian/streamside and aquatic life such as insects, snakes, frogs, and minnows. The streambanks and streamside vegetation have a low ability to store water. Banks are losing sediment to Highland Creek and will not be able to buffer high streamflows. Future low precipitation or drought will likely allow further deterioration in the condition of streambanks and streamside vegetation if wildlife use continues to be concentrated in areas with available water. Currently, Highland Creek 1 and Highland Creek 2 DMAs are providing the ecological service of water for wildlife but do not have streambank, streamside vegetation, and ecological characteristics that would allow them to provide other ecological services (although non-native brook trout are present in Highland Creek 2 DMA). All Highland Creek DMAs are better characterized as vulnerable rather than resilient to future stresses.

Data collected from this project are applicable to the sampled areas and to the complexes that representative DMAs were chosen to represent These areas were determined during DMA establishment in 2009/2010 and additional reconnaissance in 2012.

The conclusions of this project are (Table 16):

1) Highland Creek Exclosure DMA provides data on a reference condition of minimal wildlife use since exclosure construction in 1995 and characterizes only Highland Creek within the exclosure. Based on observation, no other segments of Highland Creek appear similar to the area in the exclosure. Highland Creek Exclosure DMA is representative of .04% of Highland Creek.
2) Highland Creek 2 DMA is representative of Highland Creek from WICA/Custer State Park boundary to Highland Creek Exclosure or 25% of Highland Creek.
3) Highland Creek 1 DMA is representative of Highland Creek from the Bison Corrals south to Highland Creek sink or 50% of Highland Creek.
4) 25% of Highland Creek is inside Bison Corrals and is managed for high human activity/impact.

Table 16. Complexes of Highland Creek determined in 2009/2010 and further evaluated in 2012 for similarity of streambanks and streamside vegetation. NA=Not available.

Stream complex	Length	Approximate percent of stream	Representative DMA
TOTAL Highland Creek length (North/CSP boundary to Highland Creek sink)	2000 meters (1.2 miles)	100%	NA
Segment: North/CSP boundary to Highland Creek Exclosure	500 meters	25%	Highland Creek 2
Segment: Highland Creek Exclosure	80 meters	.04%	Highland Creek Exclosure
Segment: Bison corrals	500 meters	25%	NA
Segment: south boundary of bison corrals to sink	1000 meters	50%	Highland Creek 1

At project start, it was expected that different condition ratings would be developed from different DMAs and extrapolated to similar complex areas. However, all Highland Creek DMAs were rated the same - overall in poor condition. Thus, the conclusion is that 100% of Highland Creek that was assessed is in poor condition. This means Highland Creek is not able to provide a wide range of ecological services and is at risk for further reduction in the ecological services it provides. The risk is increased by factors such as drought and high animal population numbers. Establishing more DMAs would allow results to be more defensibly applicable to the whole stream. This would also assist staff in evaluating whether management actions taken are achieving desired results. However, continuing to collect MIM data in existing DMAs alone will still allow evaluation of Highland Creek condition status and change.

Fish and macroinvertebrates were observed in Highland Creek 2 DMA with rock/gravel substrate (as opposed to fine sediment), indicating some ecological service of aquatic habitat is being provided. More specific monitoring than MIM protocol provides is needed to characterize the ecological service qualities of the aquatic habitat and its stability.

Even given its shorter length, it was expected that there would be segments of Highland Creek that wildlife rarely or lightly used – that might provide refugia for riparian plant species sensitive to grazing and trampling disturbances. However, this was not supported by DMA data or full stream reconnaissance. Determining what constitutes reference condition remains extremely difficult.

A primary purpose of this project was to provide information that would be able to serve as a foundation for management discussions on Highland Creek. It is very important to overall Highland Creek ecological services that current conditions for all segments be understood, desired conditions established, management tools affecting condition identified, and monitoring conducted appropriately to inform management choices and determine results.

VIII. Cold Spring Creek Exclosure and Cold Spring Creek 1

Table 17 presents key indicators and metrics describing Cold Spring Creek Exclosure DMA and Cold Spring Creek 1 DMA. Highlights of analysis follow.

Table 17. Key indicators of condition of Cold Spring Creek Exclosure and Cold Springs Creek 1 in 2010.

Metric	Cold Spring Creek 1	Reference/ Cold Spring Creek Exclosure	Cold Spring Creek 1 Condition
Mean stubble height (all key species)	9.7 ± 1.2 in	16.1 ± 1.4 in	High grazing in Cold Spring Creek 1 not supporting long-term plant health
Dominant key species – stubble height	Nebraska sedge 7.2 ± 2 in	Kentucky bluegrass 15.1 ± 1.0 in	High grazing in Cold Spring Creek 1 not supporting long-term persistence of key species; low grazing in Cold Spring Creek Exclosure supporting undesirable key species
Plant diversity index	12.93	13.39	Mid-range among WICA DMAs
Hydric species (%plots)	23.5 ± 6.2%	13.7 ± 6.2%	Low-range among WICA DMAs
Woody species composition	10 + 6%	32 + 6%	Low contribution of woody species
Streambank cover	44 ± 5%	95 ± 5%	High grazing in Cold Spring Creek 1 contributing to low streambank cover
Stable banks	8 ± 5%	74± 5%	High trampling/disturbances in Cold Spring Creek 1 contributing to low streambank stability
Bank alteration	79 ± 6%	5 ± 6%	High trampling in Cold Spring Creek 1 resulting in high streambank alteration
Mean greenline-to-greenline width	4.97 ± 0.30 m	3.28 + 0.30 m	High-range among WICA DMAs
Substrate	48% fines	48% fines	High fine sediment load contributing to high risk for aquatic habitat
Wetland rating	40 ± 4 - Poor	31 ± 5 - Poor	Below average contribution by wetland species
Winward greenline stability rating	3.37 ± .16 - Low	4.13 ± .16 - mid	Mid-low resistance to erosion
Greenline ecological status rating	23 ± 5 – Early	39 ± 5 – Early	Early ecological condition is not resilient

MIM streamside vegetation parameters (mean stubble height, dominant key species, height of dominant key species, plant diversity index, and percent hydric herbaceous species) for Cold Spring Creek 1 DMA relative to Cold Spring Creek Exclosure DMA indicate the grazing of streamside vegetation in Cold Spring Creek 1 DMA was high in 2010.

MIM bank parameters (percent covered bank, percent bank alteration, percent stable bank, mean greenline-to-greenline width) for Cold Spring Creek 1 DMA relative to Cold Spring Creek Exclosure DMA indicate primarily unstable streambanks in Cold Spring Creek 1 DMA in 2010.

Nebraska sedge, a desirable native hydric species, was present in Cold Spring Creek 1 DMA in 2010 and contributed to streambank stability. However, a stubble height of 7.18 inches for Nebraska sedge in Cold Spring Creek 1 DMA relative to the ungrazed mean Nebraska sedge stubble height of 22.2 inches (2010 Highland Creek Exclosure DMA) indicates a level of grazing that is not likely to be sustainable for maintaining Nebraska sedge plant health in the long-term.

Long-term metrics for wetland rating, Winward greenline rating, and greenline ecological status rating considered together indicate poor condition for Cold Spring Creek Exclosure DMA and Cold Spring Creek 1 DMA. Both DMAs have below average contribution of wetland species, mid to low erosional resistance, and early ecological status.

Based on the 2010 measurements, Cold Spring Creek 1 DMA is primarily providing one ecological service – water for wildlife. Although streamside stubble height was extremely low, rangelands/forage in adjacent stream terrace areas were not heavily grazed (B. Burkhart, pers. observations 2010). Lower residual plant material would be expected if wildlife were focusing on this stream area for forage. This suggests that wildlife primarily utilize Cold Spring Creek 1 DMA for water rather than forage. Other ecological services besides water for wildlife (e.g., supporting diverse native streamside vegetation, providing water storage and resilient streambanks, and providing conditions to support aquatic life) are very minimally provided in Cold Spring Creek 1 DMA.

The notable presence of non-native, non-hydric Kentucky bluegrass is a signal of undesirable vegetation condition in Cold Spring Creek Exclosure DMA. The low percent of hydric herbaceous species is inversely related to a high percent cover of Kentucky bluegrass on Cold Spring Creek Exclosure streambanks (captured as key dominant species). Additional investigation is needed to determine whether native, hydric species are likely to become established in this exclosure.

Kentucky bluegrass and other non-native species can be aggressive in re-establishing on streambanks that have developed a lower water storage capacity during previous periods of grazing. In addition, upland species may make a greater contribution to the vegetation of this stretch of Cold Spring Creek if it is dewatered frequently. In seasons and years where Cold Spring Creek 1 and Cold Spring Creek Exclosure DMAs have no streamflow, Great Plains upland species are able to displace hydric species – and non-native species including Kentucky bluegrass may be aggressive and competitive in establishing.

In 2012, no MIM measurements could be made because there was no water in Cold Spring Creek 1 DMA or in Cold Spring Creek Exclosure DMA. Field observations were that lack of water in this area concentrated wildlife use in Beaver Creek and on Cold Spring Creek west of the Cold Spring Creek DMAs. Additional DMAs are needed to characterize use of Cold Spring Creek as a whole. Based on reconnaissance in 2010 and 2012, it is likely that Cold Spring Creek is similar to Beaver Creek in that all areas of the stream are accessible to wildlife and moderately to highly used.

Cold Spring Creek Discussion (Considering All Cold Springs Creek DMAs)

A goal of this project was to characterize the range of streambank and streamside vegetation conditions on Cold Spring Creek through distribution of an achievable number of DMAs. However, only 2 DMAs were established on Cold Spring Creek. DMAs were chosen based on field observation to represent minimal wildlife use/wide valley (reference condition) and high wildlife use/wide valley. Because Cold Spring Creek was dry in the DMA areas in 2012, the project provided data from just one baseline MIM application. Establishment of additional DMAs and more MIM measurements are needed to further investigate the condition of Cold Spring Creek. However, based on field reconnaissance in 2012 of the entire length of Cold Spring Creek, it is unlikely that there are any stretches of Cold Spring Creek that would fit the category of light wildlife use.

A summary of condition status in 2010 for streambank stability, streamside vegetation, and ecological condition in DMAs on Cold Spring Creek is provided in Table 18.

The length of Cold Spring Creek in WICA is ca 3500 meters. The source of Cold Spring Creek is a set of springs in an isolated parcel of WICA approximately 2 miles to the west of the main landbase of the park. A series of pipes carries the water under private land and brings it to the surface in Cold Spring Creek drainage just inside WICA. This was WICAs primary water source until Park Well #1 was drilled in 1956.

Table 18. Summary of condition status in 2010 for DMAs on Cold Spring Creek. See Table 4 for explanation of symbols.

Indicator of Condition	Stream DMA	Condition Status/Change	MIM Protocol Parameters Evaluated
Streamside vegetation	**Cold Spring Creek Exclosure**		Mean stubble height of all species; Mean stubble height of dominant species; Mean greenline-to-greenline width; Plant diversity index; Percent hydric species
	Cold Spring Creek-1		
Streambank stability	**Cold Spring Creek Exclosure**		Percent bank alteration; Percent covered banks; Percent stable banks; Mean greenline-to-greenline width
	Cold Spring Creek-1		
Ecological condition	**Cold Spring Creek Exclosure**		Wetland rating; Winward greenline stability rating; Greenline ecological status rating
	Cold Spring Creek-1		

It may be that Cold Spring Creek is the perennial stream in WICA with greatest risk of losing the ability to provide ecological services due the uncertainty about the age and integrity of the piping system from the source to WICA and the high risk of total loss of stream flow during dry conditions. In general, Cold Spring Creek DMAs highlight that the variable volumes of water and lengths of surface streams in the park are important parameters that should be documented annually and considered in WICA surface water management (covering both riparian vegetation management and wildlife management).

Discussion

Data measured and analyzed during the WICA project characterizing condition of streambanks and streamside vegetation on perennial streams in the park using the BLM MIM protocol indicate that:

1) Beaver Creek Exclosure, Beaver Creek 1, Beaver Creek 2, and Beaver Creek 3 DMAs cover a range of streambank and vegetation conditions resulting from minimal wildlife use (over the last 17 years) to intensive wildlife use. However, MIM parameters indicate poor condition in all Beaver Creek DMAs (and stable condition 2009 to 2012). Based on extrapolation of results from representative DMAs to similar segments, Beaver Creek as a whole is in poor condition. Wildlife population numbers and other disturbances and management activities stayed essentially the same in WICA from 2009 to 2012. It was not possible in this project to find a stretch of Beaver Creek representative of light use by wildlife. The most unexpected attribute of Beaver Creek was the high sediment load in all DMAs. However, this is not surprising after reviewing MIM indicators for bank alterations and unstable banks. The impacts of high sediment load on aquatic habitat (for native fish, insects, herps, macroinvertebrates, etc.) are a high risk for reducing ecological services. Maintaining Beaver Creek Exclosure is critical to developing insight into vegetation and other stream parameter potentials.

2) Highland Creek Exclosure, Highland Creek 1, and Highland Creek 2 DMAs cover a range of streambank and vegetation conditions from minimal wildlife use (over the last 17 years) to intensive wildlife use. However, MIM parameters indicate poor condition in all Highland Creek DMAs (and stable condition from 2009 to 2012). Based on extrapolation of results from representative DMAs to similar segments, Highland Creek as a whole is in poor condition. Wildlife population numbers and other disturbances and management activities stayed essentially the same in WICA from 2009 to 2012. It was not possible in this project to find a stretch of Highland Creek representative of light use by wildlife. Highland Creek had a lower sediment load than Beaver Creek but it was still notable. High levels of unstable banks and streambank alterations documented by MIM indicators provide a constant source of fine sediment to the stream. Highland Creek is a short stream with good water flow that currently sustains a non-native fishery. Its potential for high quality aquatic habitat should be further investigated. With the high wildlife use in the north section of Highland Creek, the altered/unmeasured section in the Bison Corrals, and the southern section prone over the years to loss of stream flow (due to karst dynamics), there is little area available to investigate vegetation potential for Highland Creek. Maintaining Highland Creek Exclosure is critical to developing insight into vegetation and other stream parameter potentials.

3) Cold Spring Creek Exclosure DMA and Cold Spring Creek 1 DMA data allow a preliminary assessment of streambank and vegetation conditions from an area of minimal wildlife use (over the last 17 years) and an area of high wildlife use on Cold Spring Creek. Cold Spring Creek DMAs are in poor condition. More data are needed to characterize condition of Cold Spring Creek as a whole. Cold Spring Creek may be the perennial stream in WICA with greatest risk of loss for providing ecological services due to uncertainty about the age/integrity of the piping system from its source to WICA and the high risk of losing all

stream flow during dry conditions. The inability to measure MIM parameters in Cold Spring Creek DMAs in 2012 due to lack of stream flow highlights that the variable volumes of water and lengths of surface streams in the park are important parameters to measure annually to support WICA surface water management decisions.

Based on MIM indicators, WICA perennial streams are providing an important ecological service of water for wildlife. However, other ecosystem services including browse/woody production; species richness (plant and animal); compositional, structural, and functional diversity; and hydrologic function are at risk and vulnerable to future reductions or losses.

There is not currently a body of MIM data available for Black Hills streams to provide a context for WICA data. This project is a first step in documenting MIM data for perennial streams in WICA. More data is needed from established WICA DMAs as well as additional DMAs in the park in future years to refine or adjust conclusions made based on this project. MIM data from southern Black Hills streams outside WICA would also be very helpful in establishing context and reference condition.

There are also very few published standards or specific goals for riparian management. This is partly because streams vary greatly from place to place due to geology, geomorphology, vegetation, etc. One relevant published standard is found in the USDA Forest Service Region 2 (covering Black Hills National Forest) Watershed Conservation Practices Handbook (FSH 2509.25) Chapter 10 (Management Measures and Design Criteria) (USDA 2006). Design criteria 12.1 (1.k): “Maintain the extent of stable banks in each stream reach at 74% or more of reference conditions.” A definition of reference condition is not provided (e.g. no livestock? no herbivore use? no manmade disturbances?). For a simple exercise in considering this standard at WICA, if reference condition is defined to be exclosure condition (which may not be the best reference condition, however it is the only one there is data on), the average percent stable banks for all WICA exclosures (2009, 2010, and 2012) is 84% stable banks. 75% of 84% stable banks is 63% stable banks. The average percent stable banks of all WICA non-exclosure DMAs (2009, 2010, and 2012) is 20%. Even assuming a wide margin of error, the data indicate streambank conditions in WICA that are not supportive of a perennial stream system able to produce wide-ranging ecological services.

WICA has managed its surface water in the past but has never had a comprehensive surface water management plan. Surface water management activities have ranged from large [e.g., the creation and decommissioning of Norbeck Lake on Cold Spring Creek (1929-1989)] to small (e.g., development of 15 of the park’s documented springs for wildlife; development of 14 small impoundments/dams throughout the park to hold water for wildlife. Note: many of these improvements are not fully functional today).

There are many factors that have influenced WICA surface water in the past. Wildlife numbers have fluctuated in the park since the park boundary fence was completed in 1953 (particularly elk: between highs of 800 – 1200 animals to lows of a couple hundred animals). There are no internal fences in WICA and wildlife (bison, elk, mule deer, white-tail deer, antelope, mountain lions, endangered black-footed ferrets, prairie dogs) roam freely to find and use water and forage except in developed zones such as around the Visitor Center. Precipitation levels have also fluctuated in the past. Very dry years (4 inches or greater below average precipitation) between

1952 and the present occurred in 1953, 1954, 1960, 1988, 2004, and 2006. Very wet years (7 inches or greater above average precipitation) over the same period occurred in 1982, 1993, 1995, 1998 and 2010 (WICA climate station monitoring data). High wildlife numbers and low precipitation generally lead to stresses that reduce condition of stream channels and streamside vegetation.

Climate science information, including some specific information for WICA developed in a 2010-2013 project (King et al. 2013), indicates that past history is not a good predictor of future conditions relative to climate/precipitation: temperatures are likely to be higher; precipitation may be about the same but will be effectively lower in conjunction with higher temperatures; and climate events are likely to be more intense (e.g. droughts, precipitation, etc. occurring in extreme events). Given projections of climate change impacts in WICA, it is unlikely that the limited surface water resources in WICA, especially perennial streams, will be able to provide a wide range of desired ecological services without careful management.

Because of all these factors, strategic management of WICA perennial stream water resources, including making decisions between conflicting priorities when needed, will be necessary to allow WICA streams to provide as many ecological services as possible. This project provides a foundation for development of a WICA Surface Water Resource Management Strategy that would include prioritization of desired ecological services for WICA perennial streams, identification of streams/segments with different goals and objectives, development of possible management tools (short and long term) and triggers for implementation. A novel blend of hands-off and hands-on water/wildlife/vegetation management will be needed in the future to meet WICA mission goals and allow surface water streams to provide a wide range of ecological services in the long term (supporting a dynamic vegetation system, cycling through different levels of disturbance over time, and sustaining persistent and sensitive species in temporal and geographic refugia across WICA landscape).

This project cannot answer questions about how plant species and communities have changed since the Black Hills Community Inventory in 1999 or before. Greater scrutiny and consideration of WICA streams during this project has led to some interesting ideas. Through time, southern Black Hills streams have always been used by wildlife and humans. Perennial streams in WICA had bison and other native herbivores using them in pre-European contact times. However, it is highly unlikely that they used the streams at the regularity and intensity of current use because herds were larger and moved around in a much larger, unfragmented landscape including the Black Hills and northern Great Plains. After homesteading/settlement of the Black Hills, cattle dominated the herbivore landscape. One estimate is that cattle numbers in the Black Hills rose from 100,000 to 500,000 between 1878 and 1883, managed on an "open range" basis (Palais 1942). Regularity and intensity of use on WICA perennial streams is again uncertain but animals were not restricted to any subset of the area and more intense use may have focused on larger, more dependable water sources (e.g. Fall River/springs, Beaver Creek/Buffalo Gap/springs), particularly during periods of low precipitation. The current situation of herbivore populations restricted to limited surface water on 28,295 acres in WICA is a unique phenomenon occurring only since the WICA boundary fence was completed in 1953 – roughly 50 years.

While drought and high animal population numbers have occurred before, the ability of the WICA landbase to provide refugia from disturbances is different today than it has been for most of its past. WICA herbivores live in a predator-reduced environment and use the same limited landscape with approximately 6.5 miles of surface stream every year, come wet year or dry. This likely constitutes the most consistent configuration of land/water use ever occurring on this piece of ground. There were periods of high disturbance in the past but they were experienced over a larger landscape that had the potential to include more refugia (both temporally and geographically) for plant and animal species sensitive to disturbance.

Because of these differences from the past to today and lack of data, it is not possible to know what changes occurred in plant species and plant communities as a result of past bottleneck periods of high disturbance. However, it seems certain that management of WICA riparian areas today should consider the concepts of refugia and persistence of plant species sensitive to disturbances in order to conserve and protect present-day WICA vegetation into the future. WICA has increasingly implemented thoughtful and scientifically-based wildlife management (for example, 2006 WICA Elk Management Plan Environmental Impact Statement/Record of Decision leading to recent completion of a project that upgraded WICA boundary fence to control elk ingress/egress; coordination with state, federal, and private stakeholders and substantial effort in 2012-2013 to reduce elk numbers from ca 900 animals to WICA Elk Management Plan target of 232-475 animals). However, there is room for expanded effort in holistic wildlife/vegetation/water management that would be assisted by development of a WICA Surface Water Resource Management Strategy.

Relative to speculation about riparian/streamside vegetation in 1999 (BHCI-rated as exemplary) and changes to today, it is most likely that there has been little change. However, high precipitation in the several years before and in 1999 as well as relatively low wildlife population numbers may have allowed an expression of potential in 1999 that is not seen today. Recent dry years and low precipitation in 2012, as well as high wildlife population numbers, likely impact current vegetation expression even if all the species are still present in some form (in small stands, dormant plants, seedbank, etc.).

It is true that wildlife require water – however, it is not necessary that they trample streambanks and streamside vegetation. One question to consider in a water resource strategy would be whether wildlife should continue to have full-time access to and use of >99% of WICA surface streams. On the other hand, some level/pattern of disturbance (including trampling by wildlife) is a natural process that WICA riparian/streamside plant species and communities evolved with. Without a doubt, a novel blend of hands-off and hands-on water/wildlife/vegetation management will be needed in the future to meet WICA mission goals and allow surface water streams to provide a wide range of ecological services in the long term.

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Appendix A: Photographs

Photographs of all WICA Designated Monitoring Areas (DMA) – one photo at DMA start and one photo within DMA.

I. Beaver Creek Exclosure DMA

Beaver Creek Exclosure - 2010

Beaver Creek Exclosure - 2012

II. Beaver Creek 1 DMA

Beaver Creek 1 - 2009

Beaver Creek 1 – 2012

III. Beaver Creek 2 DMA

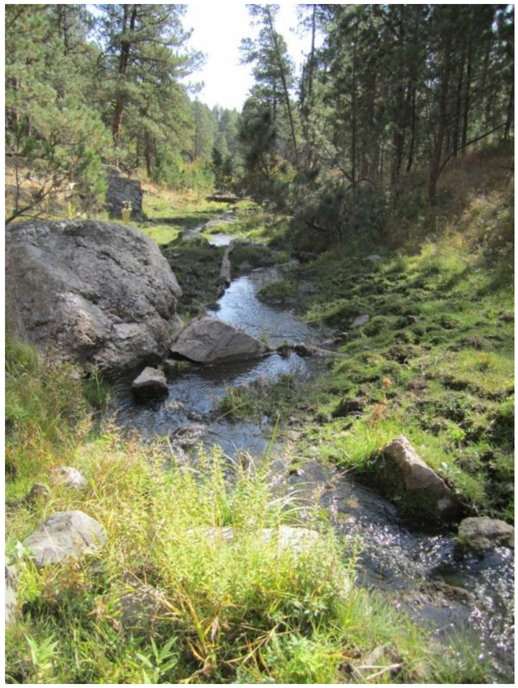
Beaver Creek 2 – 2009

Beaver Creek 2 – 2012

IV. Beaver Creek 3 DMA

Beaver Creek 3 – 2009

Beaver Creek 3 – 2012



V. Highland Creek Exclosure DMA

Highland Creek Exclosure – 2010

Highland Creek Exclosure – 2012

VI. Highland Creek 1 DMA

Highland Creek 1 – 2009

Highland Creek 1 – 2012

VII. Highland Creek 2 DMA

<u>Highland Creek 2 – 2009</u>

<u>Highland Creek 2 – 2012</u>

VIII. Cold Spring Creek Exclosure DMA

Cold Spring Creek Exclosure – 2010

Cold Spring Creek Exclosure – 2012

IX. Cold Spring Creek 1 DMA

Cold Spring Creek 1 – 2010

Cold Spring Creek 1 – 2012

Appendix B: MIM Data Analysis Module - Spreadsheets for all WICA Designated Monitoring Areas (DMA)

Summary Analysis

DMA =	Beaver Creek 1 2009
Pasture =	East of cold springs confluen
Date =	8/11/2009

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
3.50	4.2	CANE2	3.87	5.5%	82%	0%	4%	0%	91%	9%
n=	80	46		19	80	80	80	0	58	6
95% conf Int[1]	0.7		1	2%	1%	*	*	2		
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

	Vegetation Ratings			Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	13	63	4.06	5.43		#DIV/0!
Rating	**Very early**	**Good**	**Mid**			
n=	168	168	168	80	0	79
95% conf Int[1]	*	4.9	*	0.38		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	12	78	3.89
Rating	**Very early**	**Good**	**Low**
n=	168	168	168
95% conf Int[1]	*	4.9	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	0	0	0	0	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
	VEGETATION							
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	11	0%	37%	12.61	57%	2%	50	56.5%
n=	79	0	62	168	95	3		95
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

Summary Analysis

DMA = Beaver Creek 1 2012

Pasture = 0.00

Date = 8/29/2012

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
2.50	3.0	CANE2	2.66	6.7%	92%	0%	3%	100%	0%	0%
n=	80	59		21	80	80	80	73	0	0
95% conf Int[1]	0.5		0	2%	1%	*	*	2		
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

	Vegetation Ratings			Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	10	65	3.88	4.85		#DIV/0!
Rating	**Very early**	**Good**	**Low**			
n=	186	186	186	80	0	78
95% conf Int[1]	*	4.5	*	0.35		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	22	77	4.44
Rating	**Early**	**Good**	**Mid**
n=	186	186	186
95% conf Int[1]	*	4.5	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	100%	0.3	1.00	2	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	200	200	200	200	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	8	1%	28%	13.16	51%	1%	27	51.1%
n=	78	1	52	186	95	1		95
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis

DMA = Beaver Creek 2 2009

Pasture = 0.00

Date = 8/12/2009

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
16.00	15.8	AGST2	16.07	5.0%	34%	49%	95%			
n=	69	43		52	80	80	80	0	0	0
95% conf Int[1]	1.2		2		2%	*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	38	69	4.87	2.69		#DIV/0!
Rating	**Early**	**Good**	**Mid**			
n=	205	205	205	80	0	69
95% conf Int[1]	*	4.7	*	0.17		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	12	74	2.83
Rating	**Very early**	**Good**	**Low**
n=	205	205	205
95% conf Int[1]	*	4.7	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	0	0	0	0	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	68	100%	29%	14.92	58%	4%	87	55.9%
n=	69	46	60	205	118	9		114
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis	DMA = Beaver Creek 2 2012	LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS
	Pasture = 0.00	LINK TO GRAPHS WORKSHEET
	Date = 8/29/2012	LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
20.00	20.7	AGST2	18.29	12.8%	68%	0%	73%	99%	1%	0%
n=	57	22		57	56	56	56	82	1	0
95% conf Int[1]	3.0		4	3%	2%	*	*	0		
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	33	74	4.26	2.58		#DIV/0!
Rating	**Early**	**Good**	**Mid**			
n=	142	142	142	57	0	57
95% conf Int[1]	*	4.3	*	0.15		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	15	73	2.94
Rating	**Very early**	**Good**	**Low**
n=	142	142	142
95% conf Int[1]	*	4.3	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	0	0	0	0	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	71	17%	27%	13.01	58%	1%	148	57.7%
n=	57	17	39	142	82	2		82
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis	DMA = Beaver Creek 3 2010	LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS
	Pasture = 0.00	LINK TO GRAPHS WORKSHEET
	Date = 8/12/2010	LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
11.00	11.8	CAREX	15.10	20.1%	54%	24%	86%	0%	43%	57%
n=	73	29		28	80	80	80	0	3	4
95% conf Int[1]	1.4		2	7%	2%	*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	12	62	4.43	2.76		#DIV/0!
Rating	**Very early**	**Good**	**Mid**			
n=	193	193	193	80	0	73
95% conf Int[1]	*	3.7	*	0.16		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	1	64	3.41
Rating	**Very early**	**Good**	**Low**
n=	193	193	193
95% conf Int[1]	*	3.7	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	27%	2.3	12.83	75	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	181	181	181	181	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	56	36%	12%	14.71	48%	3%	36	47.2%
n=	73	4	24	193	93	6		91
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

Summary Analysis

DMA = Beaver Creek 3 2012

Pasture = 0.00

Date = 9/19/2012

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
10.00	10.1	CAREX	15.14	33.9%	69%	16%	75%	0%	40%	60%
n=	78	22		72	80	80	80	0	2	3
95% conf Int[1]	1.4		2	5%	2%	*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	10	52	3.51	3.56		#DIV/0!
Rating	**Very early**	**Fair**	**Low**			
n=	246	246	246	80	0	75
95% conf Int[1]	*	4.6	*	0.29		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	-3	56	2.47
Rating	**Very early**	**Fair**	**Low**
n=	246	246	246
95% conf Int[1]	*	4.6	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	0	0	0	0	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	49	89%	34%	18.91	32%	4%	86	30.5%
n=	75	40	83	246	78	9		75
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

Summary Analysis

DMA =	Beaver Creek Exclosure 2010
Pasture =	Beaver Creek Exclosure
Date =	9/29/2010

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
15.00	16.5	POPR	14.61	3.6%	1%	79%	90%	100%	0%	0%
n=	69	33		99	70	70	70	1	0	0
95% conf Int[1]	1.3		1		0%	*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	15	43	3.01	2.61		#DIV/0!
Rating	**Very early**	**Fair**	**Low**			
n=	144	144	144	70	0	69
95% conf Int[1]	*	4.5	*	0.10		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	6	48	2.36
Rating	**Very early**	**Fair**	**Low**
n=	144	144	144
95% conf Int[1]	*	4.5	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	68%	0.6	1.77	24	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	279	279	279	279	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
	VEGETATION							
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	73	98%	11%	9.39	37%	19%	117	36.8%
n=	69	62	16	144	53	28		53
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis

DMA =	Beaver Creek Exclosure 2012
Pasture =	0.00
Date =	9/10/2012

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
16.00	16.2	AGST2	13.19	5.0%	6%	87%	100%	0%	50%	50%
n=	58	26		65	60	60	60	0	1	1
95% conf Int[1]	1.5		1		1%	*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	7	54	3.20	2.44		#DIV/0!
Rating	**Very early**	**Fair**	**Low**			
n=	155	155	155	60	0	58
95% conf Int[1]	*	4.9	*	0.13		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	-7	62	2.23
Rating	**Very early**	**Good**	**Low**
n=	155	155	155
95% conf Int[1]	*	4.9	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	0	0	0	0	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**

VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	73	96%	31%	13.26	46%	10%	109	45.8%
n=	58	44	48	155	71	16		71
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

Summary Analysis

DMA = Cold Spring Crk Excl 2010

Pasture = 0.00

Date = 9/8/2010

[LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS]

[LINK TO GRAPHS WORKSHEET]

[LINK TO CORRELATION MATRIX]

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
16.00	16.1	POPR	15.11	5.0%	5%	74%	95%	0%	100%	0%
n=	56	36		71	62	62	62	0	8	0
95% conf Int[1]	1.4		1		1%	*	*	0		
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	39	31	4.13	3.28		#DIV/0!
Rating	**Early**	**Poor**	**Mid**			
n=	146	146	146	62	0	56
95% conf Int[1]	*	5.4	*	0.30		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	23	23	3.13
Rating	**Early**	**Poor**	**Low**
n=	146	146	146
95% conf Int[1]	*	5.4	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	48%	0.0	5.51	96	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	310	310	310	310	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	78	88%	10%	13.39	16%	32%	131	13.7%
n=	56	57	14	146	23	46		20
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis		
DMA = Cold Spring Creek 1 2010		LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS
Pasture = 0.00		LINK TO GRAPHS WORKSHEET
Date = 8/26/2010		LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
8.00	9.7	CANE2	7.18	10.3%	79%	8%	44%			
n=	79	19		69	80	80	80	0	0	0
95% conf Int[1]	1.2		2	2%	1%	*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

	Vegetation Ratings			Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	23	40	3.37	4.97		#DIV/0!
Rating	**Early**	**Poor**	**Low**			
n=	183	183	183	80	0	79
95% conf Int[1]	*	4.5	*	0.21		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	8	36	2.43
Rating	**Very early**	**Poor**	**Low**
n=	183	183	183
95% conf Int[1]	*	4.5	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	48%	0.0	6.00	160	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	330	330	330	330	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
	VEGETATION							
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	40	100%	9%	12.93	23%	10%	107	23.5%
n=	79	53	17	183	43	19		43
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] **95% conf Int: 95% confidence interval based upon standard deviation from sample data**

[2] **95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix**

Summary Analysis

DMA = Highland Creek 1 2009

Pasture = 0.00

Date = 8/14/2009

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
10.00	11.3	AGST2	11.78	8.9%	57%	26%	81%			
n=	75	32		65	80	80	80	0	0	0
95% conf Int[1]	1.0		2	2%	2%	*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	24	62	4.49	2.65		#DIV/0!
Rating	**Early**	**Good**	**Mid**			
n=	201	201	201	80	0	75
95% conf Int[1]	*	4.2	*	0.22		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	9	70	3.18
Rating	**Very early**	**Good**	**Low**
n=	201	201	201
95% conf Int[1]	*	4.2	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	37%	0.0	9.23	48	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	330	330	330	330	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	54	100%	18%	18.48	52%	5%	90	52.2%
n=	75	58	37	201	105	10		105
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis

DMA = Highland Creek 1 2012

Pasture = 0.00

Date = 8/30/2012

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
7.00	7.2	AGST2	6.56	13.7%	63%	15%	65%	89%	0%	4%
n=	73	21		119	80	80	80	25	0	1
95% conf Int[1]	0.8		1	3%	2%	*	*	0		
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	22	52	3.70	2.82		#DIV/0!
Rating	**Early**	**Fair**	**Low**			
n=	185	185	185	80	0	73
95% conf Int[1]	*	4.7	*	0.21		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	5	46	2.40
Rating	**Very early**	**Fair**	**Low**
n=	185	185	185
95% conf Int[1]	*	4.7	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	#DIV/0!	0.0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	0	0	0	0	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	39	74%	28%	19.08	33%	5%	212	33.0%
n=	73	78	52	185	61	9		61
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis

DMA = Highland Creek 1 2012

Pasture = 0.00

Date = 8/30/2012

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
7.00	7.2	AGST2	6.56	13.7%	63%	15%	65%	89%	0%	4%
n=	73	21		119	80	80	80	25	0	1
95% conf Int[1]	0.8		1	3%	2%	*	*	0		
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	22	52	3.70	2.82		#DIV/0!
Rating	**Early**	**Fair**	**Low**			
n=	185	185	185	80	0	73
95% conf Int[1]	*	4.7	*	0.21		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	5	46	2.40
Rating	**Very early**	**Fair**	**Low**
n=	185	185	185
95% conf Int[1]	*	4.7	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	#DIV/0!	0.0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	0	0	0	0	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	39	74%	28%	19.08	33%	5%	212	33.0%
n=	73	78	52	185	61	9		61
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis

DMA = Highland Creek 2 2009

Pasture = 0.00

Date = 8/20/2009

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
4.00	4.7	CANE2	4.07	10.1%	62%	16%	43%			
n=	78	35		58	80	79	79	0	0	0
95% conf Int[1]	0.7		1	4%	2%	*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

	Vegetation Ratings			Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	38	66	4.57	2.51		#DIV/0!
Rating	**Early**	**Good**	**Mid**			
n=	246	246	246	80	0	76
95% conf Int[1]	*	4.2	*	0.20		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	45	75	4.73
Rating	**Mid**	**Good**	**Mid**
n=	246	246	246
95% conf Int[1]	*	4.2	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	26%	0.0	11.25	46	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	330	330	330	330	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	26	100%	29%	22.72	45%	4%	74	44.1%
n=	76	43	71	246	111	9		108
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis

DMA = Highland Creek 2 2012

Pasture = Highland Creek 2 2012

Date = 8/30/2012

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
2.80	4.1	CANE2	2.83	26.9%	46%	20%	66%	20%	60%	0%
n=	79	42		76	79	80	80	1	3	0
95% conf Int[1]	0.8		1	6%	1%	*	*	0		
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	30	58	3.98	2.49		#DIV/0!
Rating	**Early**	**Fair**	**Low**			
n=	175	175	175	78	0	77
95% conf Int[1]	*	4.3	*	0.19		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	21	56	3.29
Rating	**Early**	**Fair**	**Low**
n=	175	175	175
95% conf Int[1]	*	4.3	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	#DIV/0!	0.0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	0	0	0	0	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
	VEGETATION							
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	32	93%	32%	15.42	36%	3%	91	35.0%
n=	77	62	57	175	64	6		62
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis

DMA = Highland Crk Exclosure 2010

Pasture = 0.00

Date = 9/9/2010

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
19.00	20.0	CANE2	22.16	5.0%	0%	95%	100%			
n=	44	25		44	44	44	44	0	0	0
95% conf Int[1]	2.0		2			*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	36	58	4.89	2.74		#DIV/0!
Rating	**Early**	**Fair**	**Mid**			
n=	120	120	120	44	0	44
95% conf Int[1]	*	5.5	*	0.37		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	37	64	5.03
Rating	**Early**	**Good**	**Mid**
n=	120	120	120
95% conf Int[1]	*	5.5	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	59%	0.0	3.18	18	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	220	220	220	220	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**
VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	83	100%	7%	17.36	52%	15%	82	51.7%
n=	44	40	8	120	62	18		62
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Summary Analysis

DMA =	Highland Crk Exclosure 2012
Pasture =	0.00
Date =	9/12/2012

LINK TO PROPER FUNCTIONING CONDITION (PFC) ANALYSIS

LINK TO GRAPHS WORKSHEET

LINK TO CORRELATION MATRIX

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all Key species (inches))	*Average SH for all key species (inches)*	*Dom key species for SH*	*Avg Ht of dom key species (inches)*	*Woody Species Use - all woody species (%)*	*Streambank Alteration (%)*	*Streambank stability(%)*	*Streambank cover (%)*	*Percent seedlings*	*Percent Young*	*Percent Mature*
5.00	5.4	CANE2	4.44	5.0%	90%	3%	45%			
n=	40	27		55	40	40	40	0	0	0
95% conf Int[1]	0.8		1		2%	*	*			
95% CI[2]	**0.96**			**5%**	**6%**	**5%**	**5%**	**7%**	**7%**	**7%**

	Vegetation Ratings			Width and Shade		
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*	*Greenline-greenline width (m)*	*Average Woody Plant Height (m)*	*Shade Index*
	7	60	4.54	2.77		#DIV/0!
Rating	**Very early**	**Fair**	**Mid**			
n=	129	129	129	40	0	40
95% conf Int[1]	*	4.6	*	0.36		*
95% CI[2]	**5.75**	**3**	**0.16**	**0.30**		

Vegetation Ratings Using Plot-Weighted Composition			
	Greenline Ecological Status Rating	*Site Wetland Rating*	*Winward greenline stability rating*
	13	66	4.35
Rating	**Very early**	**Good**	**Mid**
n=	129	129	129
95% conf Int[1]	*	4.6	*
95% CI[2]	**5.75**	**3**	**0.16**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools			
	Percent fines	*D16 Particle Size (mm)*	*D50 Particle Size (mm)*	*D84 Particle Size (mm)*	*Total number pools*	*Pool Frequency (#/mile)*	*Mean Residual Depth - All (m)*	*Mean Residual Depth - >.06 (m)*
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
n=	0	0	0	0	0	0	0	0
95% CI[2]	**11.6**					**14**	**0.06**	**0.06**

VEGETATION								
	Vegetation Biomass Index	*Percent Rhizomatous Woody*	*Percent Forbs*	*Plant Diversity Index*	*Hydric plants (%)*	*Woody composition (%)*	*Woody Species Frequency (N)*	*Hydric Herbaceous (%)*
	30	100%	18%	14.09	50%	9%	85	49.6%
n=	40	38	23	129	64	12		64
95% CI[2]					**6.2**	**5.9**		**6.2**

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

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National Park Service
U.S. Department of the Interior

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